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# NAVAL POSTGRADUATE SCHOOL

## Monterey, California



THESIS

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ANALYSIS OF CONSOLIDATION OF  
INTERMEDIATE LEVEL MAINTENANCE FOR  
ATLANTIC FLEET T700-GE-401 ENGINES

by

Jeffrey S. Cook

June, 1992

Thesis Advisor:

Keebom Kang

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Analysis of Consolidation of  
Intermediate Level Maintenance for  
Atlantic Fleet T700-GE-401 Engines

by

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Submitted in partial fulfillment  
of the requirements for the degree of

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## ABSTRACT

This thesis is an analysis of consolidation of duplicate capabilities for intermediate level maintenance of T700-GE-401 turboshaft engines belonging to Naval Air Force, Atlantic Fleet. The down-sizing of the military in the next decade and the resulting budget constrained reality will force the Navy to adopt innovative measures to save costs. One of the methods by which costs can be reduced is by combining the maintenance functions of activities with duplicated capabilities into one facility, as is proposed for the maintenance facilities for this engine. To test the feasibility of the consolidation concept, the thesis uses simulation to model an Aircraft Intermediate Maintenance Department (AIMD) operating as a consolidated T700 maintenance facility under a worst-case scenario. Based on the simulation results, the thesis concludes that the proposed consolidation is a viable concept. The thesis also uses life cycle cost analysis to quantify *some of the cost savings resulting from the consolidation*. Specific recommendations are then made regarding implementation of the consolidation concept.

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## TABLE OF CONTENTS

I. INTRODUCTION . . . . .	1
II. BACKGROUND . . . . .	5
A. THE NAVAL AVIATION MAINTENANCE PROGRAM . . . . .	6
1. Levels of Maintenance . . . . .	6
a. Organizational Level Maintenance . . . . .	7
b. Intermediate Level Maintenance . . . . .	8
c. Depot Level Maintenance . . . . .	9
B. T700-GE-401 ENGINE . . . . .	11
1. Background . . . . .	11
2. Engine Characteristics . . . . .	11
a. Cold Section Module . . . . .	12
b. Hot Section Module . . . . .	13
c. Power Turbine Module . . . . .	13
d. Accessory Module . . . . .	13
3. T700 Reliability and Maintenance . . . . .	14
a. Reliability . . . . .	14
b. Maintenance . . . . .	16
C. AIRCRAFT INTERMEDIATE MAINTENANCE DEPARTMENT . . . . .	18
1. Organization . . . . .	18
a. Production Control . . . . .	19
b. Material Control Center . . . . .	20

c.	Quality Assurance/Analysis . . . . .	20
2.	Power Plants Division . . . . .	21
a.	Third Degree Repair . . . . .	21
b.	Second Degree Repair . . . . .	22
c.	First Degree Repair . . . . .	22
d.	Repair Beyond First Degree . . . . .	23
e.	Manning and Training . . . . .	23
3.	AIMD Mayport Power Plants Division . . . . .	24
4.	AIMD Jacksonville Power Plants Division . . . . .	27
5.	CV AIMD Power Plants . . . . .	29
6.	NAS Sigonella AIMD . . . . .	30
III.	SIMULATION OF CONSOLIDATED AIMD POWER PLANTS . . . . .	31
A.	OVERVIEW OF SIMULATION . . . . .	31
1.	Description of SIMAN . . . . .	32
a.	SIMAN Model Classifications . . . . .	33
b.	Probability Distributions . . . . .	34
B.	DEVELOPMENT OF THE AIMD MODELS . . . . .	40
1.	AIMD T700 Power Plants Model 1: Third Degree Repair . . . . .	41
2.	AIMD T700 Power Plants Model 2: First Degree Repair . . . . .	44
C.	LIMITATIONS AND PARAMETERS FOR AIMD SIMULATION MODELS . . . . .	47
1.	AIMD Operating Hours and Repair Channels . . . . .	48
2.	Number of Aircraft and Engines . . . . .	50

3.	Mean Time Between Failure . . . . .	52
4.	Flight Hours / Engine Requirements . . . . .	53
5.	Engine Spares . . . . .	56
6.	Engine and Module Service Times . . . . .	57
7.	Engine Failure Breakout Percentage by Module . . . . .	58
D.	SIMULATION RESULTS AND ANALYSIS . . . . .	60
1.	Third Degree AIMD Model . . . . .	60
2.	First Degree Repair AIMD Model . . . . .	63
3.	Combination Simulation . . . . .	66
IV.	COST ANALYSIS . . . . .	70
A.	PRODUCTION AND CONSTRUCTION COSTS . . . . .	71
B.	OPERATIONAL AND MAINTENANCE COSTS . . . . .	72
C.	LIFE CYCLE COST ANALYSIS . . . . .	73
1.	Cost Factors Used in Analysis . . . . .	74
2.	Results of Cost Analysis . . . . .	76
V.	CONCLUSIONS AND RECOMMENDATIONS . . . . .	78
A.	SUMMARY . . . . .	78
B.	CONCLUSIONS . . . . .	78
C.	RECOMMENDATIONS . . . . .	79
1.	Elimination of NAS Sigonella and CV Capability . . . . .	80
2.	Military Construction Requirement . . . . .	81
3.	NAS Mayport AIMD as the Consolidated Site . . . . .	82



4. Current Engine Problems and Spares	
Requirements . . . . .	84
a. Current Engine Problems . . . . .	85
b. Engine Spares Requirements . . . . .	86
VI. FINAL REMARKS . . . . .	88
LIST OF REFERENCES . . . . .	89
APPENDIX A . . . . .	91
APPENDIX B . . . . .	95
APPENDIX C . . . . .	100
APPENDIX D . . . . .	102
APPENDIX E . . . . .	107
APPENDIX F . . . . .	116
INITIAL DISTRIBUTION LIST . . . . .	117

## LIST OF TABLES

TABLE 3.1 - SEAHAWK/T700 MTBF . . . . .	52
TABLE 3.2 - SEAHAWK FLIGHT HOUR PROJECTIONS (HOURS PER AIRCRAFT) . . . . .	53
TABLE 3.3 - PROJECTED FY97 SEAHAWK ENGINE FAILURES/MONTH . . . . .	55
TABLE 3.4 - PROJECTED FY97 SEAHAWK ENGINE FODS PER MONTH . . . . .	55
TABLE 3.5 - PROJECTED T700 SPARE REQUIREMENTS . . . . .	57
TABLE 3.6 - MEAN SERVICE TIMES . . . . .	58
TABLE 3.7 - ENGINE MODULE FAILURE BREAKOUT . . . . .	59
TABLE 3.8 - THIRD DEGREE AIMD MODEL SIMULATION RESULTS	62
TABLE 3.9 - FIRST DEGREE AIMD MODEL SIMULATION RESULTS	64
TABLE 3.10 - COMBINED AIMD MODEL SIMULATION RESULTS . .	67
TABLE 4.1 - MILITARY PERSONNEL, NAVY COSTS . . . . .	75
TABLE 4.2 - 30 YEAR LIFE CYCLE COST ANALYSIS RESULTS .	76

## LIST OF FIGURES

FIGURE 2.1 - ENGINE REMOVALS/1000 FLIGHT HOURS . . . .	15
FIGURE 2.2 - AIMD (ASHORE) ORGANIZATION . . . . .	19
FIGURE 2.3 - AIMD MAYPORT POWER PLANTS ORGANIZATION AND MANNING . . . . .	25
FIGURE 2.4 - AIMD JACKSONVILLE POWER PLANTS AUGMENTED ORGANIZATION AND MANNING (PROPOSED) . . . . .	29
FIGURE 3.1 - POISSON DISTRIBUTION . . . . .	35
FIGURE 3.2 - EXPONENTIAL DISTRIBUTION . . . . .	36
FIGURE 3.3 - NORMAL DISTRIBUTION . . . . .	37
FIGURE 3.4 - TRIANGULAR DISTRIBUTION . . . . .	38
FIGURE 3.5 - LOG NORMAL DISTRIBUTION . . . . .	39
FIGURE 3.6 - BLOCK DIAGRAM: THIRD DEGREE CONSOLIDATED POWER PLANTS MODEL . . . . .	42
FIGURE 3.7 - BLOCK DIAGRAM: FIRST DEGREE CONSOLIDATED POWER PLANTS MODEL . . . . .	45
FIGURE 3.8 - SEAHAWK FLEET GROWTH BY COMMUNITY . . . .	51
FIGURE 3.9 - SEAHAWK FLEET GROWTH BY VERSION . . . . .	51
FIGURE 3.10 - SEAHAWK FLEET FLIGHT HOURS . . . . .	54

## I. INTRODUCTION

In his 1992 State of the Union Address, President George Bush announced that his FY-93 budget submission would cut fifty billion dollars from the Department of Defense. He then said, in regard to further defense reductions "This deep, but no deeper." Unfortunately for the Department of Defense, in the aftermath of the Cold War with the euphoria over the "Peace Dividend," further cuts in the U.S. military budget below the levels requested by the President are virtually inevitable. It is practically a daily occurrence for a political pundit or a Member of the House or Senate to propose a pet program funded from "savings in the defense budget."

We, in the Navy, have to recognize these political and budget realities. The Navy is going to have to be innovative in finding methods to make the best utilization of scarce funding resources while retaining fleet capabilities and readiness. One area in which the Navy can conserve funds is in the consolidation of duplicate maintenance capabilities. Consolidation is the process of combining these duplicate capabilities and placing them under the control of a single maintenance facility. If properly done, consolidation can result in cost savings by reducing manpower, equipment, and spares inventories, yet not have an adverse impact on fleet support.

In Naval Aviation, aircraft maintenance support at the intermediate level is typically provided by the Aircraft Intermediate Maintenance Department (AIMD) of the Naval Air Station (NAS) at which the aircraft are based. This policy, while on the whole very successful and an effective way to provide maintenance support at this level, resulted in some similar or duplicate intermediate maintenance facilities at Naval Air Stations in the same geographic area.

There are four metropolitan areas in the United States with more than one major AIMD within a forty mile radius. These are: Jacksonville with NAS Jacksonville AIMD, NAS Mayport AIMD, and NAS Cecil Field AIMD; Norfolk with NAS Norfolk AIMD and NAS Oceana AIMD; San Diego with NAS North Island AIMD and NAS Miramar AIMD; and San Francisco with NAS Alameda AIMD and NAS Moffett Field AIMD. (The Navy will close NAS Moffett Field in October, 1994). Thus, an area to investigate for potential cost savings lies in the consolidation of duplicate maintenance capabilities at these facilities.

Most of the Naval Air Stations mentioned have different types of aircraft based at them, and thus have equipment and facilities peculiar to the requirements of the aircraft they support. However, NAS Jacksonville and NAS Mayport both support the SH-60 Seahawk helicopter, (albeit different variants of the aircraft). AIMD NAS Mayport supports the SH-60B LAMPS III for the Helicopter Antisubmarine, Light (HSL)

community, while AIMD NAS Jacksonville supports the SH-60F for the Helicopter Antisubmarine (HS) community. Common to both variants of the SH-60 aircraft is the engine, the General Electric T700-GE-401. Each airframe has two engines installed.

The objective of this thesis is to examine the feasibility of consolidating the intermediate level maintenance of the T700 engine in the Jacksonville area, the impact of consolidation (if any) on squadron readiness, and finally and most importantly, attempt to quantify any cost savings that might result.

The thesis will study the feasibility of consolidation and effect of consolidation on aircraft readiness by using simulation modeling. The thesis will use two simulation models. The first is a simple model which assumes no T700 module repair at the consolidated AIMD, only module removal and replacement. The second is a more complex model, which assumes module repair. To demonstrate that combined AIMD support for the T700 is feasible, the intent is to attempt to overload the simulated AIMD system. To achieve this, the simulation experiments will rely on conservative or worst-case estimates of data and variables, such as number of aircraft supported, aircraft flight hours, and the mean time between failure (MTBF) figures for the aircraft.

For the cost savings portion of the problem, the focus will be on a comparative spreadsheet analysis of life cycle

costs that show a difference between separate and combined AIMD support. Emphasis will be on personnel related costs.

Many other components of the two SH-60 variants are also common to both and are good candidates for consolidated AIMD support. However, investigation of them is beyond the scope of this thesis. The scope of the thesis is limited to discussion of consolidating AIMD support for the T700-GE-401 engine.

The thesis is organized as follows. Chapter II provides a brief overview of the Naval Aviation Maintenance Program, background on the T700 engine, and a discussion of AIMD organization and capabilities. Chapter III provides an overview of simulation, describes the development of the models, details the data and assumptions used, and provides an analysis of the model results. Chapter IV describes the development of the life cycle cost models, details the data and assumptions used for them, and analyzes the results. Chapter V discusses final conclusions and recommendations. Chapter VI contains closing remarks.

## II. BACKGROUND

This thesis builds on other studies relating to consolidation of dispersed maintenance support facilities. In particular, the reader may find Wirwille and Ainsworth (1991) relevant. The thrust of their thesis was that complete consolidation of all duplicate capabilities found in the major AIMDs in the same geographic area would result in significant cost savings. This thesis is therefore a subset of their work, focusing instead on only a single duplicate capability at only one pair of major AIMDs in the same geographic area.

Krentz (1991) is also relevant, even though he discusses the next level of repair (depot). In particular, he uses queueing theory and simulation techniques to model consolidated depot repair of F404 engines and modules at Naval Aviation Depot (NADEP) Jacksonville, Florida.

Another important area associated with consolidation but not discussed in this thesis relates to spares provisioning to support the consolidated facility. Journal articles by Gross and Ince (1978) and Gross, Kahn, and Marsh (1983) are applicable. Also pertinent is a study on spare aircraft engine requirements by Evanovich and Measell (1989). Other related useful sources are mentioned in the reference list at the end of the thesis.



## **A. THE NAVAL AVIATION MAINTENANCE PROGRAM**

The Chief of Naval Operations (CNO) sponsors and directs the Naval Aviation Maintenance Program (NAMP). The CNO promulgates the program via the six volume OPNAV 4790.2E instruction series. The program sets forth the CNO's objectives, doctrine, and policies for Naval Aviation Maintenance, and provides details of programs, organizations, and responsibilities. The principal objective of the Naval Aviation Maintenance Program is to "achieve and continually improve aviation material readiness and safety standards...with optimum use of manpower, material, and funds." Achievement of this objective is made possible by repairing aeronautical equipment at the level of maintenance that attains the optimum use of resources. Also important to the achievement of the objective is protecting equipment from corrosion, conducting preventive maintenance, and gathering of data combined with its subsequent analysis to identify areas for improvement.

### **1. Levels of Maintenance**

The foundation of the NAMP is the concept of three level maintenance, which divides aeronautical maintenance into organizational, intermediate, and depot levels. This concept seeks to increase operational readiness and availability,

reduce costs, and enhance sustainability, deployability, and preparedness. It does this by providing:

- Classification of maintenance functions by levels.
- Assignment of maintenance functions to specific levels.
- Assignment of maintenance tasks to the level consistent with the depth, complexity, scope, and range required.
- Accomplishment of maintenance at a level that achieves optimum use of scarce resources.

The three levels of maintenance can be thought of as a pyramidal hierarchy, in that each higher level builds on the functions provided by previous levels. At the base of the pyramid, most generalized, and with the most numerous sites, is the organizational level. At the top, most specialized, with the least number of sites, is the depot level. An important point to bear in mind, however, is that the top two levels of the pyramid exist solely to support their customers, the individual organizations at the bottom.

***a. Organizational Level Maintenance***

Organizational (O-level) maintenance is the base level of the maintenance pyramid. It is performed at the operational site by the activity that has custody of aeronautical equipment and controls its day-to-day operation. The goal of O-level maintenance by an activity is to maintain its equipment in a mission capable status, thus supporting its own operations. O-level personnel, because of their

involvement with operations, have minimal time available for detailed maintenance tasks. Therefore, maintenance functions performed at this level are generally the simplest of the three levels. O-level maintenance functions listed in the NAMP include:

- Inspections.
- Servicing.
- Handling.
- On-equipment corrective and preventive maintenance, including on-equipment repair, removal, and replacement of defective components.
- Incorporation of technical directives (TDs).
- Record keeping and reports generation.

***b. Intermediate Level Maintenance***

Intermediate (I-level) maintenance is the mid-level of the maintenance pyramid. It is performed by maintenance activities tasked with both direct and indirect support of user activities at the O-level. The goal of I-level maintenance facilities is to enhance and sustain the mission capability and readiness of supported units by providing high quality and timely support with the lowest practical expenditure of scarce resources. I-level support facilities are located at or near the operational site whenever possible, however, this is not always the case. Maintenance personnel at the I-level usually have higher skills and a more extensive

range of support equipment available to them than personnel at the O-level, and are responsible for performing more detailed maintenance. At the I-level, a typical task is the repair of end items by removal and replacement of modules, assemblies, or piece parts. I-level functions listed in the NAMP include:

- Performance of maintenance on aeronautical equipment, components, and related support equipment.
- Calibration of designated equipment.
- Processing of aircraft components from stricken aircraft.
- Technical assistance to supported units.
- Incorporation of technical directives.
- Manufacture of selected aeronautical components, liquids, and gases.
- Performance of on-aircraft maintenance as required.

In Naval aviation maintenance, the Aircraft Intermediate Maintenance Department (AIMD) provides support at the I-level. AIMDs exist both ashore at Naval Air Stations and afloat on such vessels as aircraft carriers and amphibious assault ships. AIMD maintenance of the T700 engine is the focus of this thesis, and is discussed in greater detail later.

### *c. Depot Level Maintenance*

Depot (D-level) maintenance is the highest level on the maintenance pyramid. It is generally performed by naval aviation industrial establishments, called Naval Aviation

Depots (NADEPs). However, an increasing trend is the contracting out of D-level maintenance to depots of other services or private industry. The goal of depot maintenance activities is to support O- and I-level activities. This is done by performing maintenance beyond the capabilities of the lower levels, usually on equipment requiring major overhaul or rebuilding of end items, assemblies, and parts. Perhaps most importantly, D-level activities are tasked to ensure the continued flight integrity and safety of airframes and related flight systems throughout their service life. D-level activities have far more extensive facilities than activities at lower levels, and are not necessarily located near the activities they support. Depot level activities listed in the NAMP include:

- Standard depot level maintenance of aircraft.
- Rework and repair of engines, components, and SE.
- Calibration of equipment.
- Incorporation of technical directives.
- Modification of aircraft, engines, and SE.
- Technical and engineering assistance.
- Manufacture or modification of parts and parts kits.

## **B. T700-GE-401 ENGINE**

### **1. Background**

The Navy's T700-GE-401/401C engines are derivatives of the U.S. Army's T700-GE-700 engine developed by General Electric for the UH-60 Blackhawk helicopter. GE originally developed the T700-GE-401 engine as the powerplant for the SH-60B Seahawk. NAVAIR subsequently selected it as the engine for the Navy's SH-2G Seasprite as well as the U.S. Marine Corps AH-1T Super Cobra and VH-60 Presidential aircraft. A subsequent version, the T700-GE-401C is the designated powerplant for new production SH-60B aircraft as well as the SH-60F (CV), HH-60H (Helicopter Combat Support) and HH-60J (Coast Guard) versions of the aircraft. Additionally, older SH-60B aircraft are being retrofitted with the -401C. The -401 engines removed from these aircraft are reused in the AH-1T and SH-2G programs. The principle advances in the -401C over the standard version include cost reducing design changes as well as improvements to the centrifugal compressor and gas generator turbine which together provide a 9% increase in power at sea level.

### **2. Engine Characteristics**

The T700-GE-401/401C is a compact, lightweight front drive turboshaft engine of modular construction rated at 1540/1684 shaft horsepower, respectively. It weighs 427 lbs dry, has a length of 46 inches and a maximum diameter of 17

inches. The engine has a combination axial/centrifugal compressor, an annular combustor chamber, an air-cooled two-stage axial flow high-pressure turbine, and an independent two-stage uncooled axial flow low pressure (power) turbine. The power turbine shaft is coaxial and extends to the front of the engine where it is connected to the power output shaft via a splined joint. The compressor has variable stator vanes to aid in efficient, stall-free operation throughout the operating envelope. To protect the engine from foreign object damage, sand, and dust, it has a particle separator designed as an integral feature of the inlet section.

Fabricated of the engine is primarily of corrosion resistant steel, some of which is covered by protective coatings. Other materials include titanium in the compressor casing and aluminum in the separator frame and gearbox case.

The T700 is a modular engine constructed of four major modules, briefly described in the subsections below. Drawings of the engine and modules appear in Appendix A.

#### **a. Cold Section Module**

The cold section module includes the compressor section, diffuser, diffuser case, midframe casing assembly, and the inlet section. The diffuser and midframe casing assembly are a matched assembly. The midframe casing assembly houses the combustion liner for the hot section. The inlet section includes the components forward of the compressor

section, which are the swirl frame, main frame, output shaft, front frame, and collection scroll case.

***b. Hot Section Module***

The hot section module contains three major subassemblies: the gas generator turbine, the stage one nozzle assembly, and the combustion liner. The combustion liner is a ring type combustor cooled with secondary airflow from the diffuser case. The stage one turbine nozzle contains air cooled nozzle segments and directs gas flow to the gas generator turbine. The gas generator turbine consists of the turbine rotor assembly and the turbine stator assembly.

***c. Power Turbine Module***

The power turbine module is a self-contained, two stage, shrouded design with uncooled tips. It is comprised of the power turbine rotor, power turbine shaft, power turbine case and the exhaust frame.

***d. Accessory Module***

The accessory section mounts at the 12:00 o'clock position of the cold section module main frame. It is comprised of the accessory gear box and several accessories contained in, or mounted on, the front and rear face of the accessory gear box casing. The rear face provides drive pads for engine starter, hydromechanical unit, inlet separator blower, and a ported face pad for the overspeed and drain valve. On the front face are pads for the alternator and fuel



boost pump. A cavity is provided for the lube and scavenge pump, and the chip detector. Pads also exist for the lube and fuel filters and the oil cooler. Passages in the accessory gearbox housing convey fuel and oil between components. The accessory gearbox is driven by a bevel gear system via a radial drive shaft from the compressor rotor.

### **3. T700 Reliability and Maintenance**

#### ***a. Reliability***

The T700 is the most reliable gas turbine engine used to date to power Naval aircraft. It has an engine removal rate per 1000 flight hours that is many times better than the T-58 engine used in the H-3 Sea King helicopter. Demonstrated mean time between failure (MTBF) when installed in the SH-60B is more than 1500 flight hours. The AIMD Officer of NAS Mayport AIMD, CDR L. Hanna, stated that the engine is so reliable that his maintenance personnel suffer from "Maytag repairman syndrome."

Figure 2.1 is a graphic comparison of the engine removal rate per 1,000 flight hours for several different engines used in Naval aircraft. Note that the removal rate includes removals for all causes, which involves removals for high time and foreign object damage in addition to removals for engine failure. Graphs of removal for failure alone, or

of different time periods than that selected for Figure 2.1 exhibit the same trend seen here.

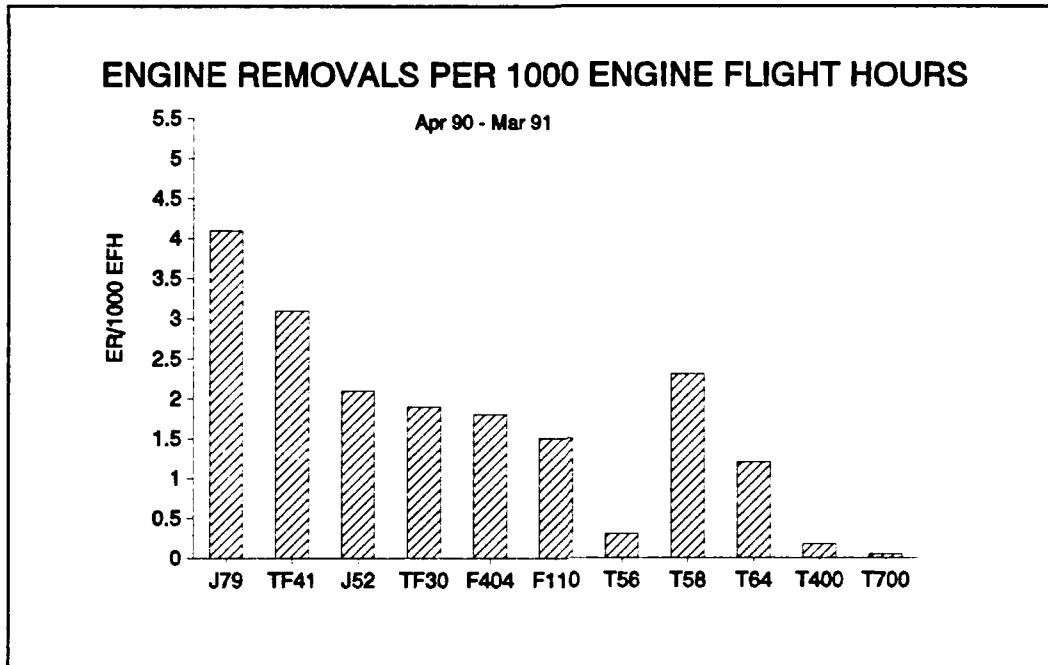


FIGURE 2.1 - ENGINE REMOVALS/1000 FLIGHT HOURS

The T700 has remarkably lower removal rates per 1,000 engine flight hours than other Naval aircraft engines. Only two engines had removal rates approaching that of the T700. The first is the T400, another modern, modular turboshaft engine. The second is the T-56 turboprop engine, which because of its installation in P-3 and C-130 aircraft, operates at a much higher number of hours per engine cycle than other engines.

**b. Maintenance**

Overhaul of the T700 engine is on a condition basis only. No designated time limit exists between overhauls. T700 maintenance follows the standard three level format of organizational, intermediate, and depot levels. The user activities providing organizational support to the Navy's T700 engines are HSL and HS squadrons. The HSL squadrons (equipped with LAMPS helicopters aboard small combatant ships) are based at NAS Mayport, NAS North Island (SH-60B), NAS Norfolk and NAS Willow Grove (SH-2G). HS squadrons (equipped with ASW helicopters aboard aircraft carriers) are based at NAS North Island and NAS Jacksonville (SH-60F).

NAS Cubi Point AIMD and NAS North Island AIMD provide first degree intermediate level support for deployed and home based West Coast SH-60 squadrons. (First degree repair is the most extensive level of intermediate support.) AIMD North Island is essentially already a consolidated T700 maintenance facility, supporting both the SH-60B and SH-60F aircraft based at NAS North Island. In addition, the pullout from Subic Bay and NAS Cubi Point means that AIMD North Island will take over the WestPac squadron support formerly provided in the Philippines.

NAS Sigonella AIMD and NAS Mayport AIMD provide first degree intermediate level support for deployed and home based East Coast SH-60 squadrons. NAS Jacksonville AIMD has recently come on line with second degree intermediate level

support. Additionally, all aircraft carrier AIMDs are scheduled to come on line for third degree intermediate level T700 support. NAS Sigonella AIMD, because of low utilization of its T700 repair capability, recently submitted a request (subsequently approved) to disestablish that capability.

For depot support of the T700, the Navy has no organic capability. Instead, the Navy sends all engines requiring depot repair to the Corpus Christi Army Depot (CCAD). Engines with failures requiring an engineering investigation are first sent to NADEP Pensacola for analysis, then are forwarded to CCAD for actual repair. CCAD provides the depot support to the T700 engines in the Army's large UH-60 Blackhawk and AH-64 Apache fleets. The Navy's T700 engines are only a small percentage of CCAD's workload, and work priorities are set by the Army.

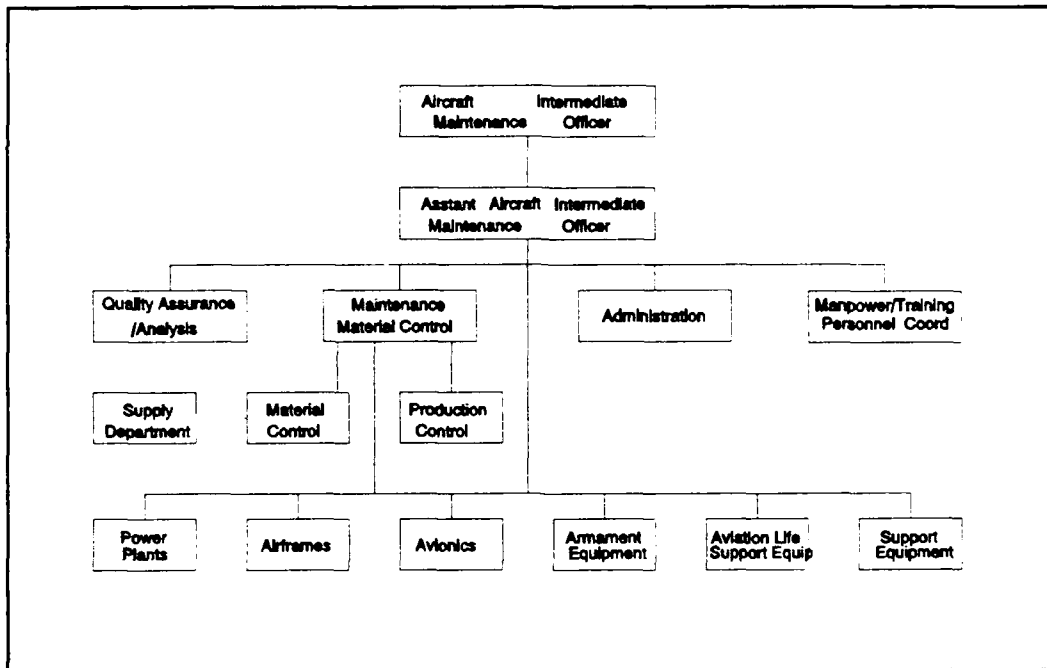
Because the Navy has no organic capability for T700 depot level repair, it has limited control over repair priorities as well as repair costs (since the Navy must reimburse CCAD for those costs). As a result, NAVAIR OP-51 requested T700 AIMDs to investigate developing repair capabilities at the intermediate level for some components and modules normally repaired at the depot level. An example of a response to this request is NAS Mayport AIMD's recent proposal to take on repair responsibility for the hot section gas generator.

### **C. AIRCRAFT INTERMEDIATE MAINTENANCE DEPARTMENT**

Aircraft Intermediate Maintenance Departments exist to provide support to the squadrons based at the host Naval Air Station. This support principally consists of indirect support provided by repair of not-ready-for-issue (NRFI) items for the base supply department pool and stocks. It also includes direct support functions such as repair and return of components sent to an AIMD by a squadron, non-destructive inspections on squadron aircraft and equipment, providing a pool of (ground) support equipment, assistance in technical directive incorporation, and many others.

#### **1. Organization**

The NAMP requires the same structure and organization for all AIMDs regardless of their location or the type(s) of aircraft they support. The goal for this standardization is effective management within a common framework of authority, functions and relationships. This allows achievement of improvements in performance, economy of operation, and quality of work. Regardless of the type of aircraft supported at each AIMD, this standardized organization functions since the type of work done in each production division involves common basic skills, techniques and capabilities. Figure 2.2 below represents the standard AIMD organization as set forth in the NAMP.



**FIGURE 2.2 - AIMD (ASHORE) ORGANIZATION**

The top three layers in the organizational chart are upper management and staff. The next layer illustrates the tie-in between AIMD and the supply department. Supply is not a part of AIMD, but must maintain a close and crucial working relationship. The bottom layer of the organization consists of the production divisions. It is the production division of Power Plants that is of particular concern to this thesis and will be examined in greater detail later. Brief descriptions of key staff divisions follow.

**a. Production Control**

Production Control is a staff function that has as its purpose the effective and efficient management of AIMD resources in support of O-level activities. Production

Control achieves this by scheduling the workload according to priorities set by the Maintenance Material Control Officer (MMCO), then coordinating and controlling production in each work center.

***b. Material Control Center***

The Material Control Center is the interface between AIMD and supply and is responsible for providing material support to the AIMD production divisions. It achieves this by forwarding requisitions for parts and material to supply in a timely manner. After receipt of these items from supply, Material Control expeditiously routes them to the applicable work centers.

***c. Quality Assurance/Analysis***

The NAMP states "The Quality Assurance concept is the prevention of the occurrence of defects." Quality Assurance/Analysis (QA/A) consists of a small group of highly skilled maintenance and administrative personnel who work toward this goal through inspection and process monitoring. The analysis function of QA/A provides a form of statistical process control. It does this by systematically gathering, analyzing, and maintaining data on the quality characteristics of AIMD's products and the source and nature of defects. QA/A has numerous specific functions including the maintenance of the AIMD central technical publications library, monitoring of calibration dates on support equipment, providing training to

production divisions in inspection techniques, ensuring that aeronautical equipment and support equipment have all required modifications incorporated, and numerous other quality related responsibilities.

## **2. Power Plants Division**

The Power Plants Division of AIMD is responsible for the inspection, repair, and subsequent testing of damaged or non-operable gas turbine engines, accessories, components. This includes units used for flight, starting purposes or auxiliary power. For engines and related items requiring D-level repair or engineering investigation, Power Plants is responsible for preservation as required and preparation for shipment. Power Plants is also responsible for maintaining accurate records and compliance with applicable power plant bulletins.

The Power Plants Division of each AIMD is classified as a first, second, or third degree repair activity for each engine type that NAVAIR authorizes them to repair. NAVAIR also makes specific assignments of degree of engine repair for each activity. Descriptions of the degrees of repair are as follows:

### ***a. Third Degree Repair***

Third degree repair is the simplest, least involved degree of I-level repair. This repair capability encompasses



major engine inspections and the removal and replacement of modules for modular engines. To qualify as a third degree repair site for a particular engine, the facility must process between one to nineteen engines of that type per year.

***b. Second Degree Repair***

Second degree repair includes all functions of third degree repair. This repair capability encompasses minor module repair by replacement of components or assemblies. According to the NAMP, this includes:

"Repair/replacement of turbine rotors and combustion sections, including afterburners; the replacement of externally damaged, deteriorated, or time-limited components, gearboxes, or accessories, and minor repairs to the compressor section. Further, the repair or replacement of reduction gearboxes and torque shafts of turboshaft engines and compressor fans of turbofan engines, which are considered repairable within the limits of the applicable intermediate maintenance manual".

To qualify as a second degree repair site for a particular engine, the facility must process more than 20 engines of that type per year.

***c. First Degree Repair***

First degree repair is the deepest degree of I-level repair. First degree repair involves analytical teardowns to determine extent of disassembly and repair required to return the engine to service. All repairs authorized for second and third degree repair can be done under this degree of repair. First degree repair can include compressor rotor replacement/disassembly. To qualify as a

first degree repair site for a particular engine a facility must process at least 50 engines of that type per year.

***d. Repair Beyond First Degree***

The NAMP provides specific guidelines as to engine discrepancies considered beyond the capabilities of a first degree AIMD. Repair of discrepancies falling in these categories is not authorized at the I-level. Instead, the engine (or module) must be forwarded to the appropriate depot for repair. The categories include:

- Engines damaged by fire or exposed to fire-fighting compounds.
- Crash damaged engines.
- Severely mishandled or dropped engines.
- Engines immersed in salt water.
- Engines with extensive corrosion damage.
- Engines with massive oil contamination.
- Engines recommended for removal by an Oil Analysis Laboratory without a readily identifiable cause of impending failure.
- Engines with severe foreign object damage.
- Engines requiring power plants changes to components not removable at the I-level.
- Engines requiring removal of life limited parts not authorized for removal at the I-level.

***e. Manning and Training***

The primary Navy enlisted rating for maintenance personnel in Power Plants is Aviation Machinist's Mates (AD).

Aviation Electrician's Mates (AE) may also be assigned to selected Power Plants work centers, such as the engine test cell. The authorized manning level of the division, as well as that of the entire AIMD is set forth in the OPNAV 1000/2 Manpower Authorization. This authorization is specifically tailored to the requirements of each organization. In addition to detailing an organization's allowed numbers of personnel in each ratings category, it specifies any Navy Enlisted Coding (NEC) requirements. The NEC system identifies skills and training necessary to fill certain billets.

A maintenance technician obtains a NEC Coding by attending a maintenance training course at a Naval Air Maintenance Training Group Detachment (NAMTRADET). NAMTRADET Mayport is the T700 training site. For T700 Power Plants divisions, the NEC codes required are:

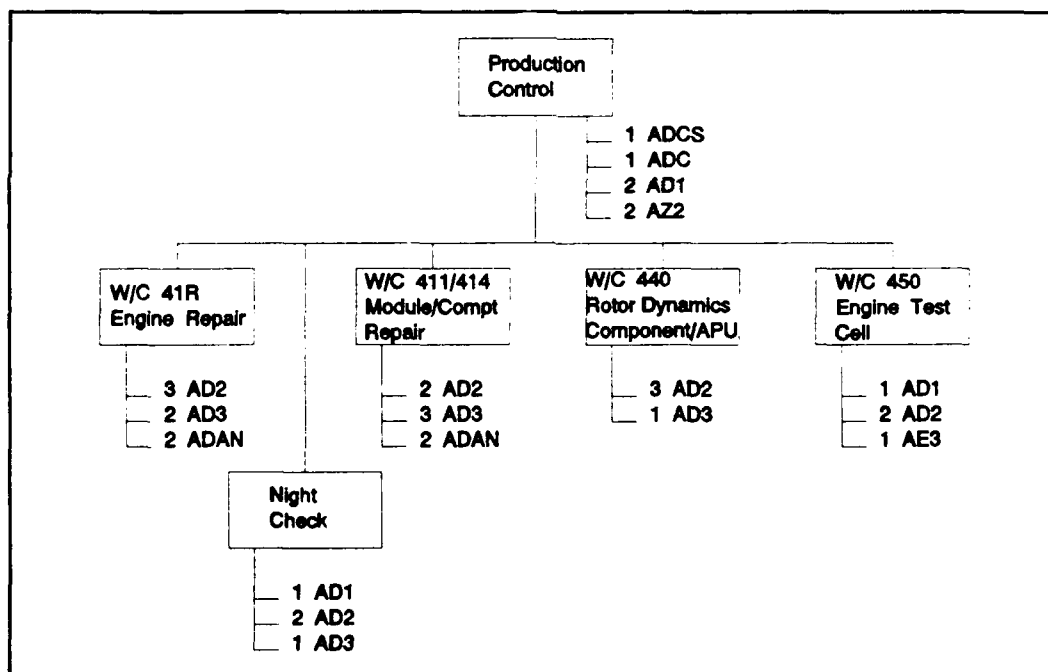
- 6426 : T700 First Degree Technician.
- 6422 : Jet Test Cell Operator.
- 6429 : Turboshaft Test Cell Operator.

### **3. AIMD Mayport Power Plants Division**

NAVAIR designated AIMD Mayport as a first degree repair site for the T700 engine and the SH-60B auxiliary power unit (APU) in June of 1985. The facilities for AIMD Mayport are relatively new, as the Navy built them specifically for

the SH-60B program, which remains the sole aircraft supported. The maintenance area for Power Plants is more than 8000 square feet. Power Plants facilities also include one T700 test cell and one APU test cell. In FY-91, AIMD Mayport processed 47 T700-GE-401 and 60 T700-GE-401C engines, for a combined total of 107, and an average of about nine engines per month.

Organization and manning of AIMD Mayport Power Plants is shown in Figure 2.3. Note that the personnel assigned to production control are staff, not production personnel.



**FIGURE 2.3 - AIMD MAYPORT POWER PLANTS ORGANIZATION AND MANNING**

The proposal by Commander, Helicopter Wings Atlantic (CHWL) to single site T700 repair suggests that in addition to

the existing manning of Figure 2.3, two additional Aviation Storekeepers (AK) are required. NAS Mayport Aviation Support Division (ASD) will designate the AKs as engine and parts managers and expeditors. Note that Aviation Administration (AZ) personnel assigned to production control are responsible for the maintenance of logs and records and other administrative duties.

AIMD Mayport Power Plants is performing only a limited amount of module repair at this time. The facility has first degree capability for the cold section and power turbine, but at present only third degree capability for the accessory gear box and the hot section. Following is a listing of currently authorized repairs at Mayport:

- Blend compressor blades.
- Replace compressor rotor assembly.
- Replace bearings 1 through 4 and supports.
- Replace turbine support assembly.
- Replace PTO assembly.
- Replace gang channel assembly.
- Replace diffuser assembly.

Replacement of the compressor rotor is a relatively new capability for AIMD Mayport Power Plants. They replaced their first one in a complete cold section build-up in February 1992.

Additionally, in April 1992, Naval Station Mayport submitted a proposal to NAVAIR to add hot section gas generator repair to AIMD Mayport's authorized first degree repairs list. The gas generator is one of the most significant T700 readiness degraders. Thirteen of the last sixteen engines repaired at Mayport had bad gas generators. At present, the gas generator has a Source, Maintenance, and Recoverability (SM&R) Code that specifies depot level repair.

#### **4. AIMD Jacksonville Power Plants Division**

AIMD Jacksonville declared T700 second degree capability late in FY-92, but have not repaired an engine to date. They expect to have SH-60 APU capability in June 1992. Jacksonville Power Plants has all the tooling, support equipment, and technical manuals required to support T700 second degree repair. Additionally, their T700 test cell was installed and calibrated in November, 1991. NAS Jacksonville's Supply Department has stocked all consumable items required to support second degree repair.

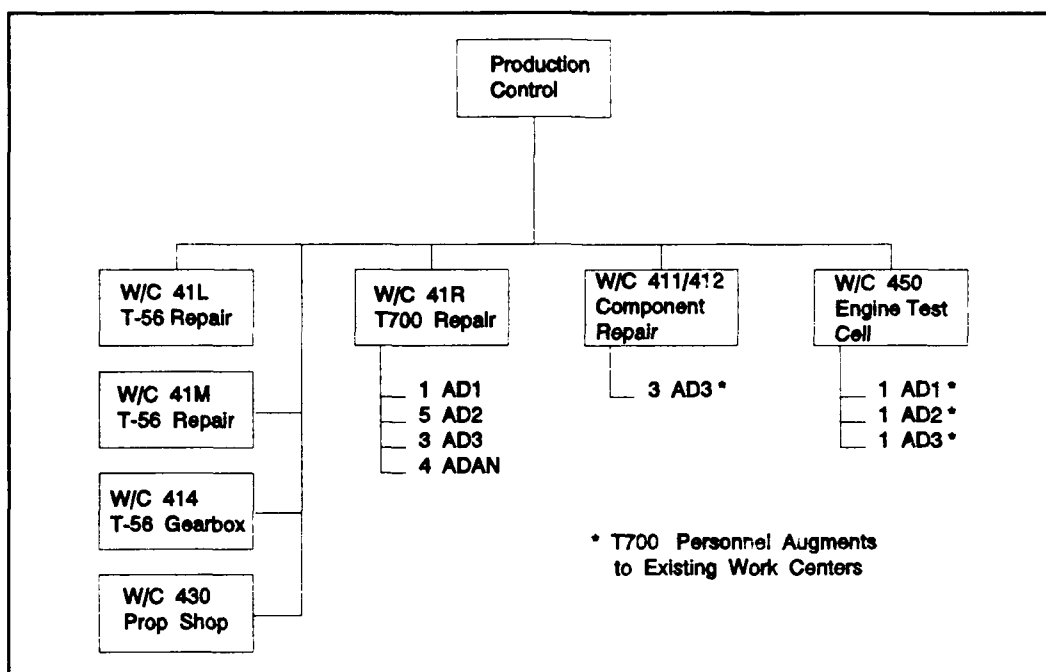
AIMD Jacksonville Power Plants Division occupied a brand-new 36,000 square foot facility in December 1991. A 10,000 square foot addition to this building for T700 maintenance is scheduled for construction in FY94. A small area for T700 maintenance will be allocated in the current

building if I-level T700 repair begins before the new construction is finished.

AIMD Jacksonville's existing Power Plants facility is primarily for the maintenance of the T-56 turboprop engine for NAS Jacksonville's large P-3 Orion community, as well as the T-58 turboshaft engines for the SH-3. Jacksonville is a designated first degree repair activity for both engines. With the scheduled closure of NAS Moffett Field, NAS Jacksonville will gain 23 additional P-3 aircraft. This will increase their T-56 workload by 15 additional engines per year, for an approximate total of 95.

Also, NAS Jacksonville does not expect their T-58 workload to drop off, even with the replacement of the SH-3 by the SH-60F. This is because the SH-3 aircraft are not scheduled for immediate retirement. Instead they will be transferred to various Naval Stations and Naval Air Stations for utilization as search and rescue (SAR) aircraft. Jacksonville will remain the I-level support site for these aircraft. The workload for the T-58 will remain steady at approximately 80 engines per year.

Figure 2.4 below is AIMD Jacksonville's proposed augmentation of their organizational structure and manning for T700 capability. Because of their existing workload AIMD Jacksonville Power Plants is a large division. AIMD Jacksonville's current staffing level is 131 enlisted personnel.



**FIGURE 2.4 - AIMD JACKSONVILLE POWER PLANTS AUGMENTED ORGANIZATION AND MANNING (PROPOSED)**

AIMD Jacksonville Power Plant's staffing level will rise by an additional 26 personnel as a result of the increased T-56 workload. However, they do not yet have an augmentation to their OPNAV 1000/2 authorizing any personnel for T700 billets. Jacksonville has attained their current T700 capability by cross training of T-58 personnel. Note that only the specific personnel added to work centers for T700 maintenance are broken out in Figure 2.4. The only all new work center required is 41R.

## **5. CV AIMD Power Plants**

Current planning calls for adding T700 third degree repair capability for AIMDs aboard aircraft carriers (and



amphibious assault ships for the USMC AH-1Ws). Adding this capability to the CV AIMD requires an additional SeaOpDet personnel billet (test cell operator) and a modification to the T-58 test cell already aboard. The modification to the test cell is the A/W37T-1 engine test system. The Naval Air Engineering Center has already received twelve of these systems, with up to 17 more on contract. Of those received, all are in storage, none are yet installed aboard ship. First scheduled CV installation is summer 1992.

#### **6. NAS Sigonella AIMD**

NAS Sigonella, Sicily, Italy AIMD is designated as a first degree intermediate repair site for the T700. It has thirteen personnel assigned to its AIMD Power Plants division for T700 support in the Mediterranean theater.<sup>1</sup>

In FY91, AIMD Sigonella repaired only eleven engines. As a result, NAS Sigonella recommended supporting theater requirements with a pool of spare engines for its supply department and disestablishing T700 repair capability.

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<sup>1</sup> The exact breakout of these personnel by paygrade is not known to the author. Therefore an assumed breakout will be used for calculations later in the thesis. The assumed breakout is: one AD1, five AD2, four AD3, and three ADAN. This is similar to the distributions by paygrade in AIMD Mayport and AIMD Jacksonville.

### III. SIMULATION OF CONSOLIDATED AIMD POWER PLANTS

#### A. OVERVIEW OF SIMULATION

Simulation is a group of techniques involving the use of computers to replicate through modeling a real-world facility or operation of interest. This facility or operation of interest is defined as a system. Simulation allows examination of the effects of changes to a system without going to the time and expense of making the changes on the genuine system. The user can explore how a system will behave with changes to the system itself, or changed inputs to the system. Simulation can help determine if a system will work before actually building it.

A system can be classified as continuous or discrete, either of which can be simulated. A continuous system is one in which the variables necessary to define the system at an instant in time change continuously over time. An example of a continuous system would be an automobile race, because the position, velocity, and acceleration of the cars change continuously with respect to time. A discrete system, on the other hand, is one in which the defining variables change only at specific and finite points in time. An AIMD is an example of a discrete system because the defining variables change

only when a component arrives for service or departs the system upon completion of service.

### **1. Description of SIMAN**

To examine the consolidated AIMD Power Plants system, this thesis uses the SIMAN simulation language (Pegden, Shannon, and Smith, 1990). SIMAN has a logic framework that breaks the simulation problem into two main components, the model and the experiment.

The model is a representation of the system developed from assumptions about how that system works or how it should work. It is a functional description of what the parts of a system are and how they interact. The model describes the physical elements of the system and their logical interrelationships. Typical examples of these elements are: machines, raw materials, people, material handling systems, and parts.

The experiment defines different variables and attributes under which the model is to be run. These include initial conditions, run length, resource availability, and types of statistics collected. Additionally, the experiment includes specifications such as resource scheduling and entity routing.

SIMAN then links the model and the experiment together and runs the simulation. At the conclusion of the simulation

SIMAN saves the responses required by the experiment as a set of output data. Because the model and experiment are separate, the user can change the conditions of the experiment without changing the model.

***a. SIMAN Model Classifications***

SIMAN models are symbolic, in that they represent the properties and characteristics of the real system in mathematical or allegorical form. SIMAN simulation models can be classified in several ways. The model, like the system, is continuous or discrete. Continuous models treat change like a ceaselessly occurring phenomenon. Continuous models are usually sets of algebraic, differential, or difference equations. A discrete model, on the other hand, describes changes to the status of a system at separate points in time. It is possible to have combination models that represent portions of the system as continuous and portions as discrete.

Models also can be classified according to time, either being static or dynamic. A static model describes the behavior of a system at a specific instant in time. Simulations using static models are typically done using spreadsheet and accounting software. A dynamic model describes the behavior of a system through time. SIMAN models are primarily dynamic.

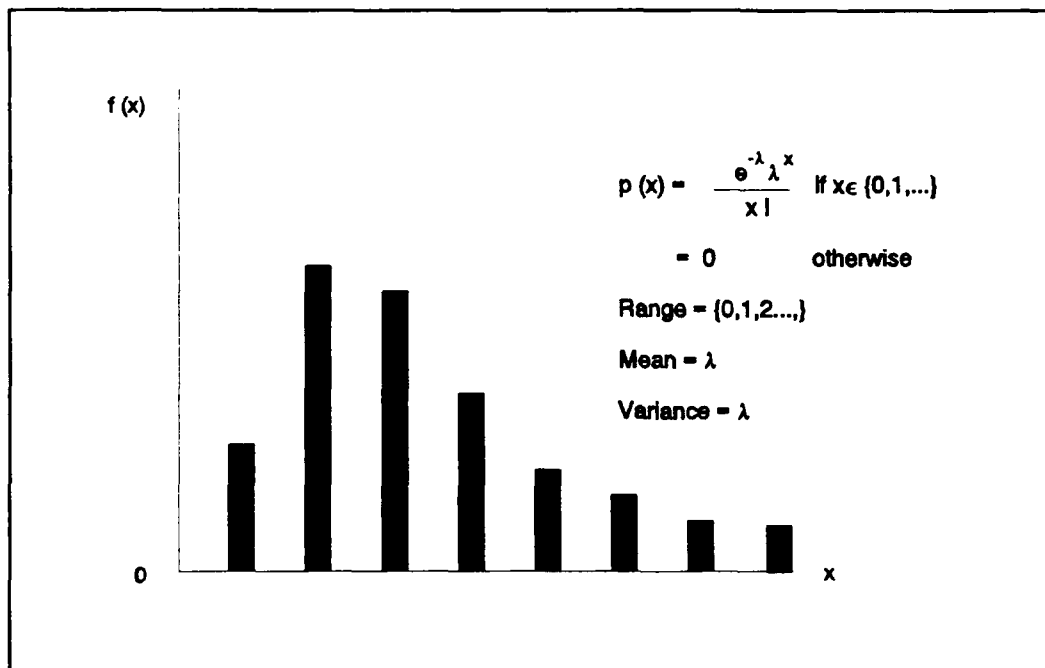
Another important way to classify models involves random variation in the system being modeled. Few real-world

systems are free from the effects of random fluctuations. A stochastic model presumes that randomness is important. Accordingly, stochastic models incorporate random elements in the model design. SIMAN models are primarily stochastic.

***b. Probability Distributions***

SIMAN can run stochastic models because it incorporates a mechanism to generate values for those random variables that influence the system. This mechanism is Monte-Carlo sampling. In this technique, a random number generator creates artificial data using a user specified probability distribution. The use of probability distributions in the generation of the random variables has an effect on the values of those variables. Accordingly, it is important to choose carefully when deciding on those distributions. Choosing inappropriate probability distributions can adversely affect the usefulness of the simulation results.

This thesis uses several types of distributions in the AIMD simulation models. The first distribution used is in the generation of failures of engines installed in aircraft. Engine failures over a specific interval of time are discrete events that occur independently. Plotting the occurrence of the number of these random failures that occur against the fixed time interval in which they occur results in a distribution pattern that closely matches the Poisson distribution. Figure 3.1 shows a typical Poisson distribution.



**FIGURE 3.1 - POISSON DISTRIBUTION**

The mean of the Poisson distribution,  $\lambda$ , is the failure rate, which is the reciprocal of the mean time between failure (MTBF). Since the time between events in the Poisson process is exponentially distributed, the time between arrivals can be modeled as exponentially distributed with a mean of  $\mu = 1/\lambda$ , or the MTBF. Therefore the models will use the exponential distribution for the arrival of failures. Figure 3.2 shows an exponential distribution.

Both AIMD models will use the exponential distribution as the distribution for the time between arrivals of the engines into the system. However, the exponential distribution may not be a good choice for generating service times for the engines. Most service times do not exhibit the high variability associated with the exponential distribution.

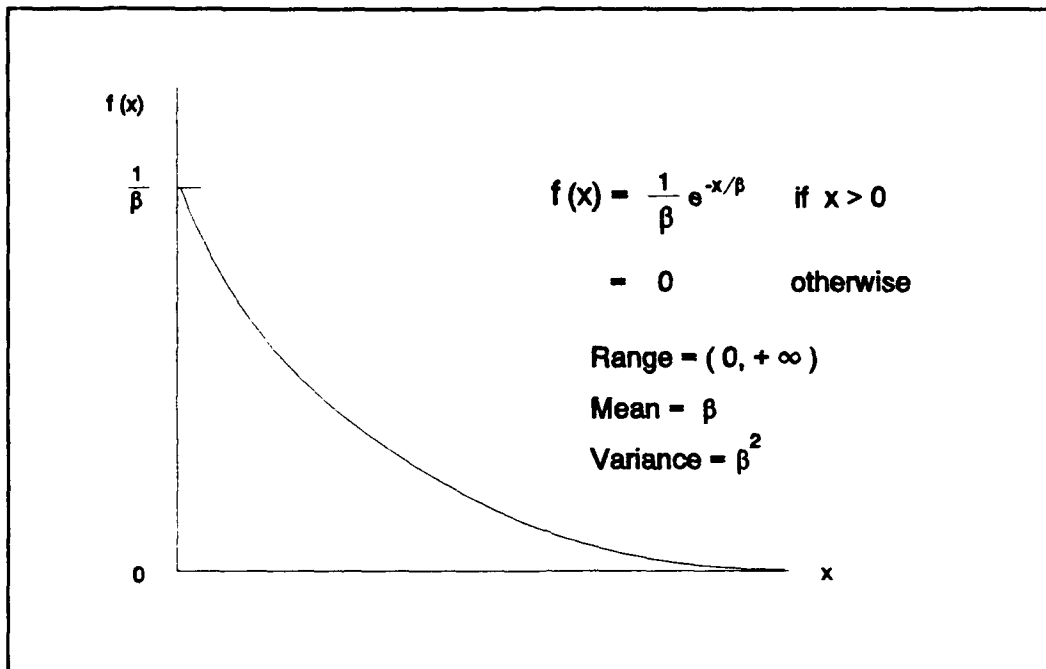
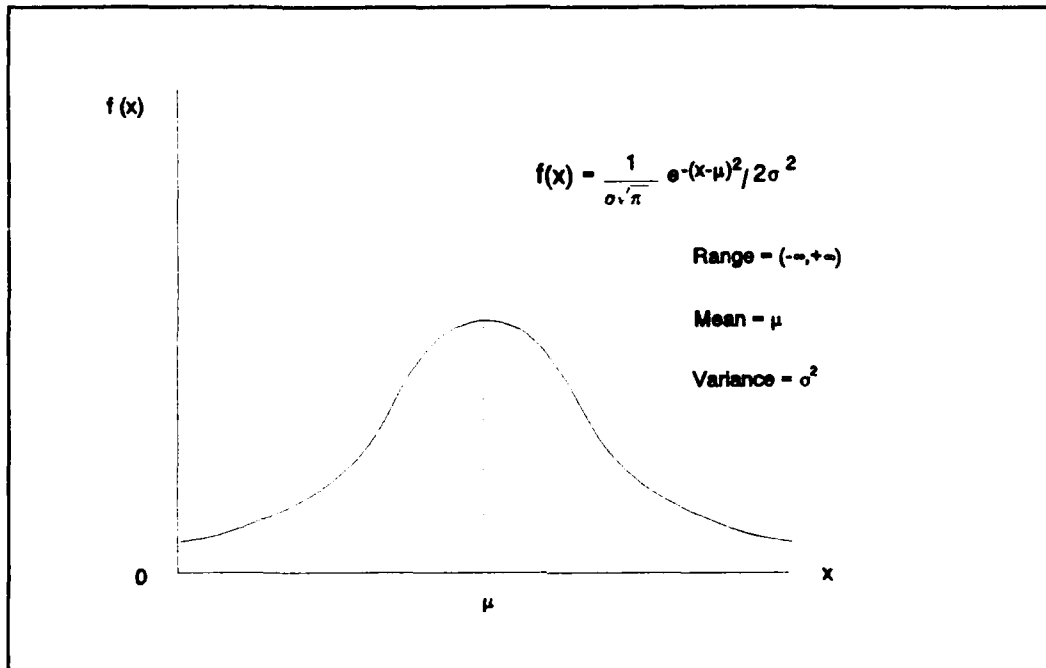


FIGURE 3.2 - EXPONENTIAL DISTRIBUTION

It might be natural to assume that the familiar bell curve of the normal distribution shown in Figure 3.3, would be a better choice for the distribution of the service times for the engines. This is not the case. The normal distribution assumes symmetric variations both above and below the mean, which is seldom true for service tasks. Experience in real-world maintenance tasks gives empirical evidence that any given task will take more time than it should far more frequently than it is accomplished in less time. A permutation of "Murphy's Law" fits here, that is, "Any task takes twice as long as it should." The effect of this on any distribution is to skew the density function to the right.



**FIGURE 3.3 - NORMAL DISTRIBUTION**

Also, to use the normal distribution with confidence, a large sample of actual service times is needed to calculate the mean and the standard deviation. For this thesis, large samples of actual service times were not readily available. Instead, the available data used is AIMD Mayport's estimate of the mean time for each service.

Pegden, Shannon, and Sadowski (1990) and Law and Kelton (1982) both suggest that two useful distributions to introduce variability with limited or absent data are the triangular and the beta distributions.

The triangular distribution, shown in Figure 3.4, has simplicity as its primary advantage. It is defined by three values: a minimum, mode, and maximum. The mode is the data value (service time) that occurs most frequently. The



service times fall in the interval defined by the minimum and maximum values.

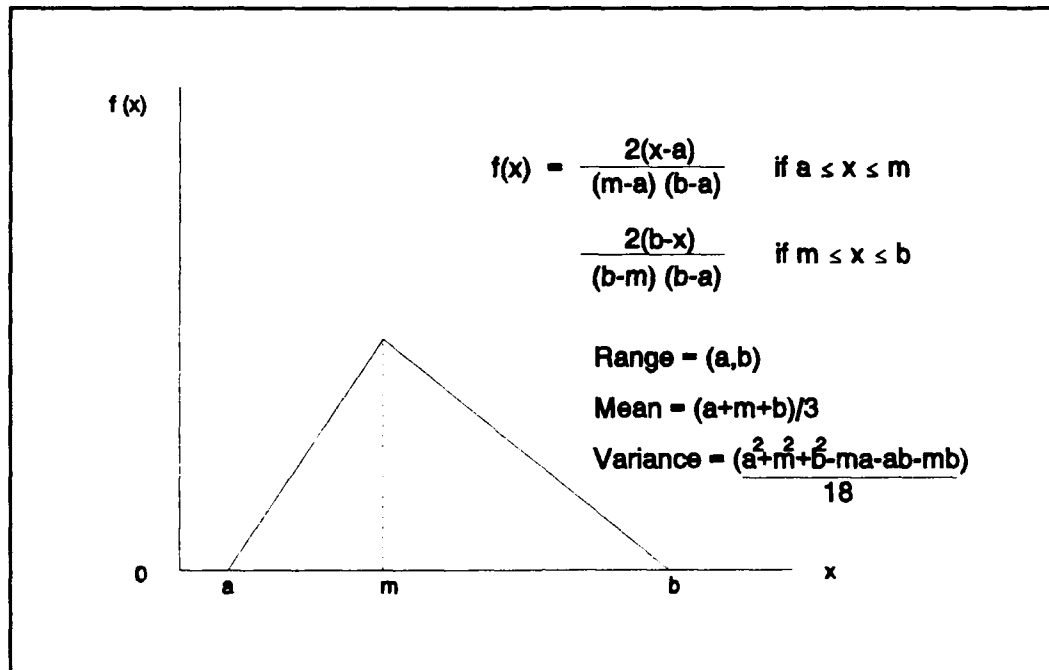


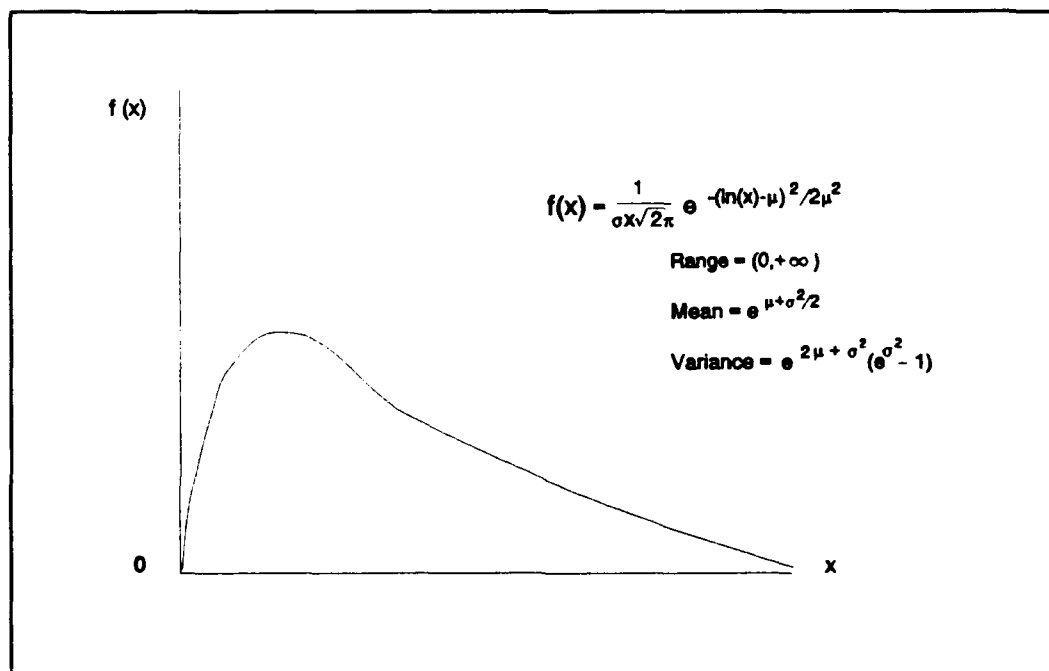
FIGURE 3.4 - TRIANGULAR DISTRIBUTION

For the triangular distributions in this thesis, the modes can be estimated from the data, but the values of the minimum and maximum are not known. Therefore, these values must be assumed. The assumed value of the minimum is 80% of the mode, and the assumed value of the maximum is 140% of the mode. This allows for the skewing to the right of the mode in the distribution that empirical maintenance experience suggests for service times.

The second distribution suggested is the beta distribution. This distribution is positive only on the interval 0 to 1. This means that the user must transform the

x values of the model to fit within this range. Also, it is not clear how to choose the two distribution parameters  $\alpha_1$  and  $\alpha_2$ , which specify the shape of this distribution. Law and Kelton do suggest that the parameters chosen should skew the density function to the right. The resulting distribution will then correspond to the empirical distribution for service times. Because of the difficulties in using the beta distribution, however, it will not be used by the models.

Instead, an alternative to the beta distribution is to use the log normal distribution. This distribution, shown in Figure 3.5, is also skewed to the right and thus also fits empirical experience for service times.



**FIGURE 3.5 - LOG NORMAL DISTRIBUTION**

The log normal distribution also avoids the pitfalls of the beta distribution. In the models, the parameters for this distribution are mean service times and the standard deviations of those times. For the AIMD simulations, the mean service time is known, but the standard deviation (variance) of the service times are not known. As a result, it is necessary to estimate the standard deviation. The estimate of standard deviation that this thesis will consistently use for the log normal distribution is a value of 30% of the mean. This value provides enough variability to the service times to generate a useable distribution, but not such substantial variability that arbitrarily large (and meaningless) spreads result in that distribution.

Simulation results may vary depending on the distributions used, and on the parameters used for the distributions. This thesis will not attempt to conduct simulations with all possible permutations of the selected distributions. Instead, representational runs of both AIMD simulation models will be made using the triangular and log normal distributions with parameters as described.

## **B. DEVELOPMENT OF THE AIMD MODELS**

SIMAN models a system by observing the entities that move through it. The SIMAN model is a description of the processes the entities undergo as they move through the system. Entities are any person or object whose movement through the

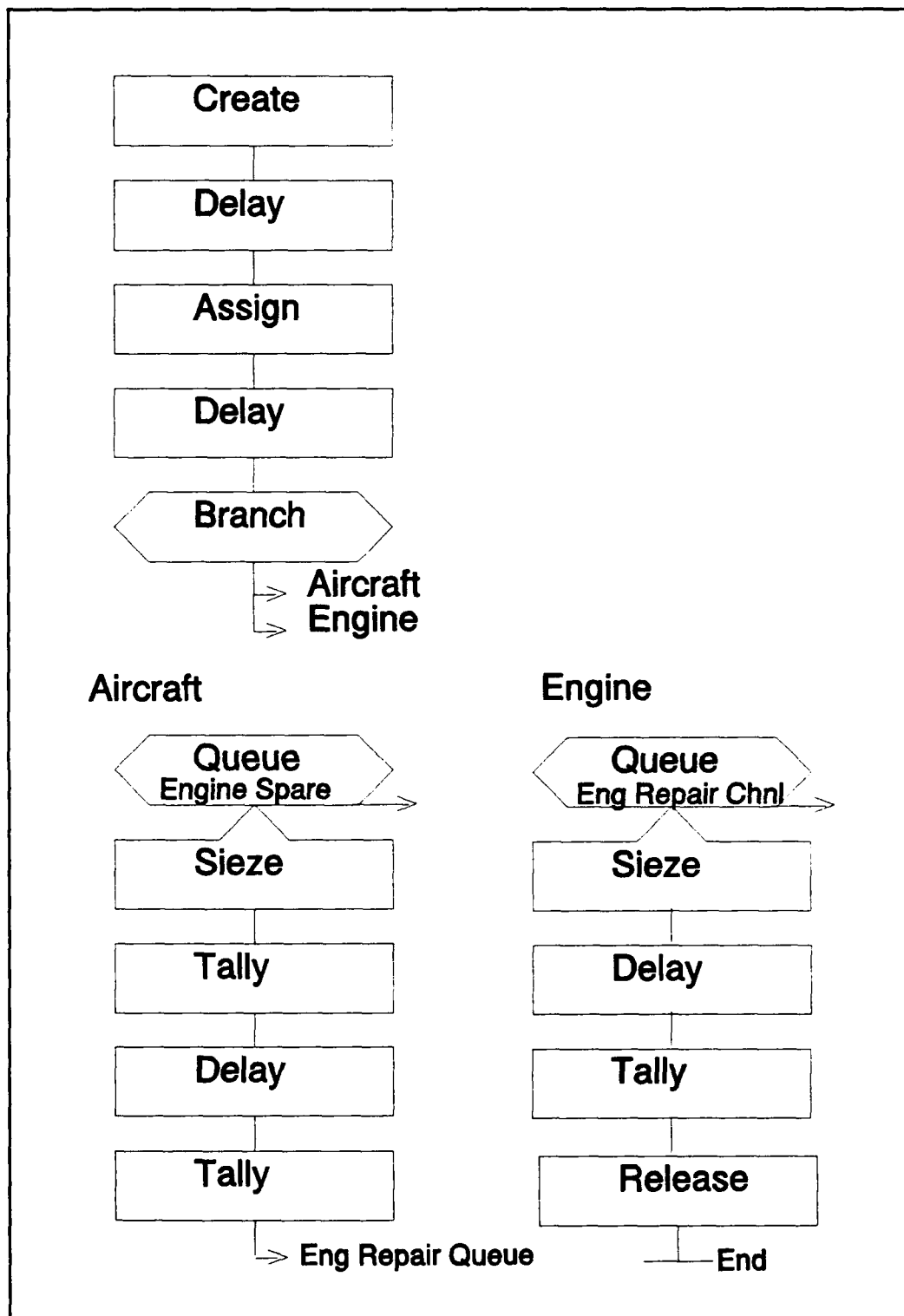
system causes a change in the system. A process is the sequence of operations through which the entities move. For the AIMD models, entities are either aircraft or engines. Processes are the repair or service actions the entities go through during the repair cycle.

SIMAN models processes with block diagrams, which are linear, top-down flow diagrams constructed of a sequence of blocks. SIMAN blocks have standardized shapes that serve as an indicator of their function. Each of the ten basic block types have numerous specific functions, each of which has its own function name. The block diagrams for the AIMD models follow SIMAN shape and naming conventions. Additionally, in the thesis text, block names will use the SIMAN convention of all capital letters.

#### **1. AIMD T700 Power Plants Model 1: Third Degree Repair**

The first model used in this thesis models the consolidated AIMD Power Plants work center as simply as possible. The primary assumption made to achieve this simplicity is that the AIMD functions as a third degree repair facility. This means the AIMD removes and replaces engine modules only, no actual module repairs of any kind are done.

Figure 3.6 on the next page is a block diagram of this model. See Appendix B for complete descriptions of both T700 AIMD models and their experiment parameters.



**FIGURE 3.6 - BLOCK DIAGRAM: THIRD DEGREE CONSOLIDATED POWER PLANTS MODEL**

In the block diagram, Figure 3.6, the simulation process starts at the CREATE block. This block sets the number of aircraft with installed engines in the system. The next block is a DELAY block, which generates engine failures at the squadron. No failed engines exist at the initiation of the simulation. ASSIGN sets the clock at the start of the simulation and assigns a time to each entity (aircraft or engine) moving through it. The next DELAY block accounts for engine removal time. The BRANCH block splits the process into two subroutines or segments.

The first segment is the aircraft engine queue. In this segment the aircraft with the engine removed "checks" the engine spare pool at the QUEUE block. If a ready-for-issue (RFI) engine is available, the aircraft takes it at the SEIZE block, installs it at the next DELAY command, then exits the system. TALLY commands collect times in the system for various entities. If, however, a spare engine is not available, then the aircraft remains grounded and must wait in the queue for the next available engine. Once the aircraft seizes an engine, it can finish its travel through the system.

Meanwhile, in the engine repair queue segment, at the QUEUE block, the failed engine must wait in the queue if no repair channels are available. Once a repair channel is available, the engine grabs it at the SEIZE block, and gets repaired at the DELAY block. The repaired engine then exits the repair channel and moves to the RFI engine pool.

## **2. AIMD T700 Power Plants Model 2: First Degree Repair**

The second Power Plants model of the thesis treats the AIMD as a first degree repair facility, where AIMD repairs modules, rather replacing them. The repair process modeled is analogous to that of a job shop facility. In a job shop, work centers are organized around type of equipment or operations. Jobs then move through the facility in a routing sequence determined by the job type. In the AIMD, as the engines move through the facility, the work centers process them in a predefined visitation sequence for each failure mode. When the sequence is completed, the repaired engines depart the facility.

Figure 3.7 is a block diagram of the first degree repair model. Unlike the third degree model, the first degree model is concerned with the engine repair flow internal to AIMD only. It treats the engine as already removed from the aircraft when it arrives from the CREATE and DELAY blocks. ASSIGN sets the clock as in the previous model, but also assigns the probability of engine failure type. The ROUTE block sends the failed engine to the STATION block.

The STATION block is the start of a submodel in which the engine arrives, waits in the QUEUE for the first work center on its visitation list, and "grabs" the first repair channel available at the SEIZE block. The work center completes its repair action at the DELAY block and is set free at the RELEASE block to begin work on the next repair.

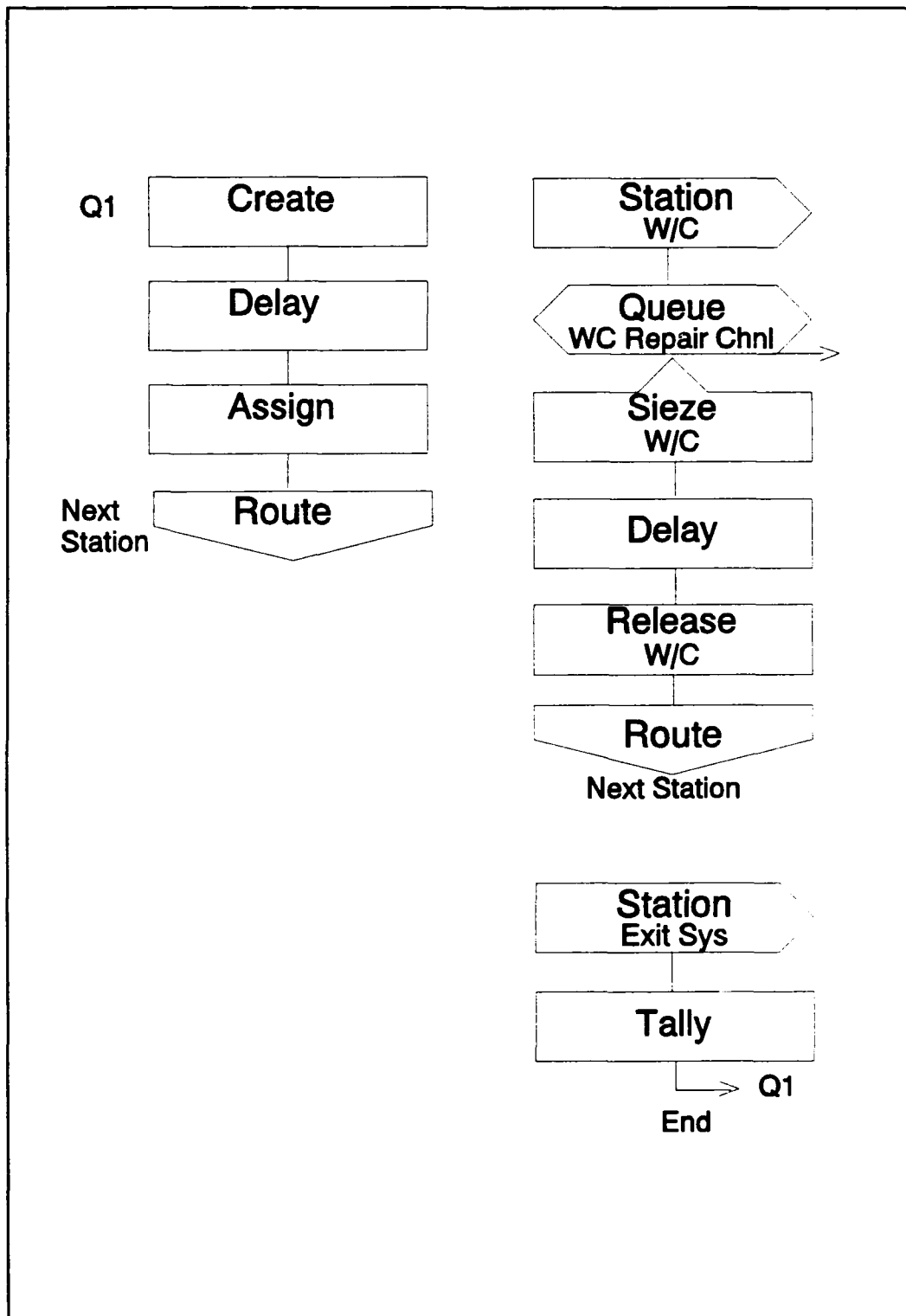


FIGURE 3.7 - BLOCK DIAGRAM: FIRST DEGREE CONSOLIDATED POWER PLANTS MODEL



Meanwhile, the engine is then sent at the ROUTE block back to the start of the submodel and the next work center on its visitation sequence list. The engine continues to go through the submodel loop until the visitation sequence is completed. The repaired engine then exits the system.

For simplification, the first degree model process assumed no module spares. The repair process in this model maintains engines as intact units as they move through the system for repair. By contrast, the real-world AIMD removes defective modules and installs a replacement module from the pool if one is available. Repaired engines are returned to service as soon as possible and defective modules are repaired independently and returned to the spare module pool.

Consequently, unlike the first model, this model by itself is a poor indicator of the relationship between aircraft downtime and AIMD engine maintenance time. What it does do well is demonstrate what the work loading of each work center is liable to be. It is also a useful model for indicating whether or not any particular work center is likely to be a bottleneck.

The first degree Power Plants model also assumes no module is beyond capability of maintenance (BCM) for AIMD. Of course, in the real-world AIMD, this is not true. Some modules will still require repair at the depot level. Doing all module repairs in-house is a worst-case, and therefore more conservative, assumption for AIMD work loading.

### C. LIMITATIONS AND PARAMETERS FOR AIMD SIMULATION MODELS

Both simulation models have several assumptions that simplified model development but limit their direct comparison to the real-world system. The most important of these is that the models ignore all logistics and administrative delay time. The models also assume location of all supported aircraft, engines, and spare engines at Mayport. Therefore, the models treat even forward deployed aircraft and prepositioned spare engines as if they are home-based. The third degree model assumes a ready-for-issue (RFI) engine from the pool or the repair loop is "instantly" available for installation in the next aircraft in the queue with an engine requirement.

Recall the reason for the simulation models is to test the feasibility of a consolidated T700 AIMD. The purpose of the simulation is not to model the complete real-world turnaround time for an engine. Rather, all the simulation needs to show is that the AIMD can service the maximum number of engine arrivals in a given time interval without having engines build up in an awaiting maintenance queue. A queue of unrepaired engines awaiting parts to complete repair will not be repaired any faster if there are more AIMDs to repair them. Therefore, awaiting parts times, shipping times, and administrative delay times are not of concern to the analysis.

Discussion follows of important model parameters, such as: mean time between failure (MTBF), service times, and number of repair channels, aircraft and engines.

### **1. AIMD Operating Hours and Repair Channels**

AIMD Mayport currently operates on a two shift basis (day/night) with a weekend duty section. Day shift and night shift work eight hours per day, five days per week, four weeks per month. This is 160 operating hours for each shift, totaling 320 hours per month. Additionally, the duty section works five hours per day, four days per month, for a total of 20 hours per month. Therefore, AIMD Power Plants is open a total of 340 hours per month.

For the models, 340 hours defines the length of a month, not the real-world month of 720 hours (30 days x 24 hours/day). It is assumed AIMD Mayport will not increase its operating hours in the event of consolidation.

Combining available man-hours per month for Power Plants work centers 41R, 411/414, 440, night check, and duty section gives a total of 3,620 man-hours available to AIMD Power Plants each month. This figure assumes 100% worker availability for each 8 hour day in the month. Since on any given workday of a month human workers take time off from production for lunch, breaks, meetings, conversations, sickness, vacations, etc., this is not a realistic projection of productive man-hours. Therefore, it is assumed that workers are only available for productive work for 80% of the 3,620 man-hours figure, or 2,896 man-hours. This equates to 6.4 productive man-hours per man per 8 hour day.

Dividing the 2,896 man-hours per month total by the 340 AIMD operating hours per month gives an average of 8.52 work center man-hours per AIMD operating hour. Any assigned repair on a module or engine is assumed to require an average of 1.7 people in work at any given time. Therefore, a repair channel is equivalent to roughly 1.7 people, and each repair channel requires that number of man-hours. To simplify the models, all repair channels are assumed open for the total length of the AIMD month, regardless of real-world hours each work center actually operates.

Allocation of the roughly 8 1/2 work center man-hours per AIMD hour at the rate of 1.7 man-hours per model repair channel provides five possible channels. These are distributed as two channels each for work centers 41R and 411/414, and one channel for work center 440. Night check and duty section are not allocated to a specific channel since they are not limited to performing work in any particular area. Instead, they are used to augment any day shift work center that is behind schedule or needs assistance on high priority tasks.

All work center repair channels, except for the test cell, are limited in capacity by man-hours, not equipment. The test cell is limited by both man-hours and equipment capacity. Only one engine can run on each cell at a time, and two personnel are required to run each cell.

The test cell work center normally operates on a day check only basis. Mayport has a single T700 cell at present.

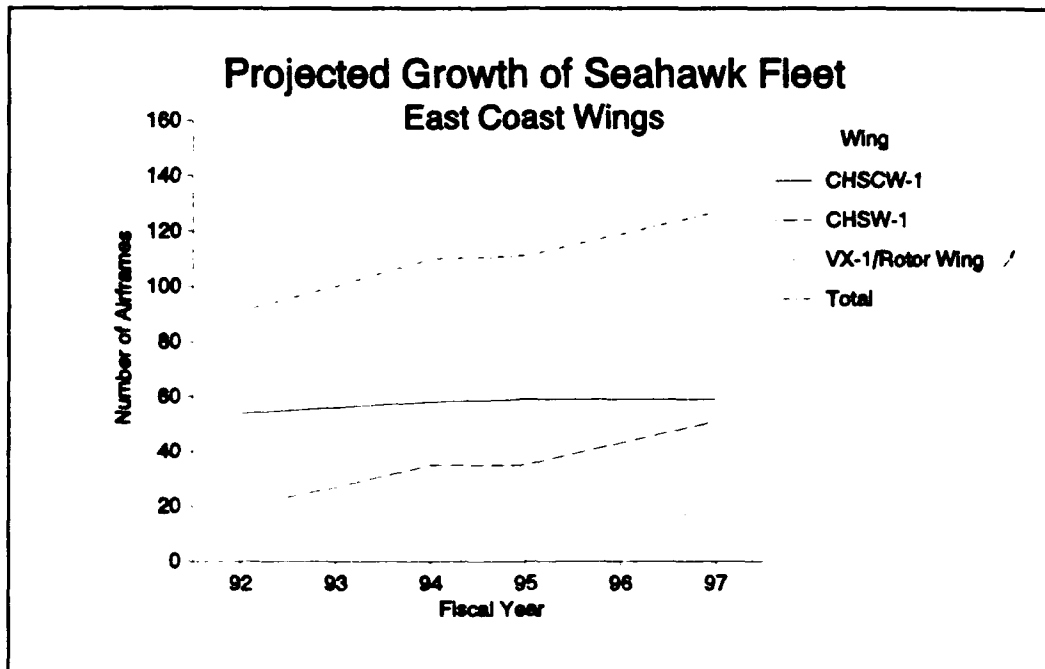
The proposed elimination of AIMD Sigonella as a T700 repair site will free up its test cell. This cell would be shipped to Mayport and become the second cell for that facility.

For the test cell work center, man-hours with 100% worker availability are 640 per month. Work center productive man-hours per month are assumed at 80% of this total, or 512 man-hours. Dividing this by AIMD operating hours gives an average of 1.5 test cell man-hours per AIMD operating hour. Since a test cell requires two man-hours per operating hour, this figure is 75% of the manning requirement for a full 340 hour per month test cell channel. As an assumption to simplify the models, a full channel will be used for the test cell.

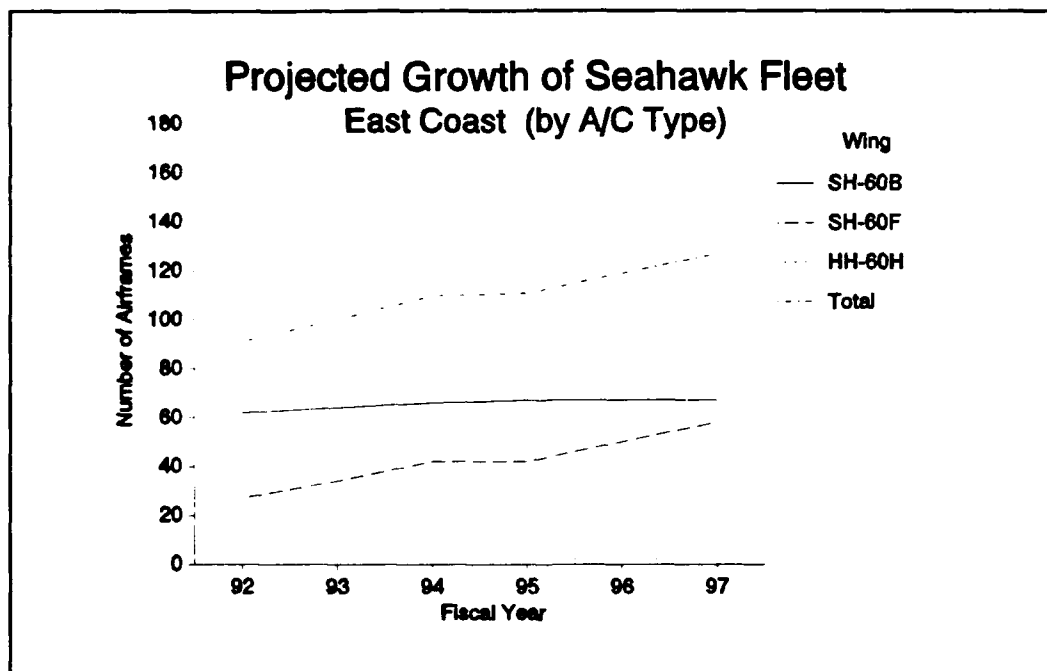
## **2. Number of Aircraft and Engines**

The number of East Coast Seahawk aircraft will continue to rise through FY 97, at which point the size of the aircraft fleet will level off. The proposal by CHWL to consolidate T700 intermediate maintenance at AIMD Mayport provided projections of the growth in the Seahawk fleet.

These projections are summarized graphically in Figures 3.8 and 3.9. Figure 3.8 shows the growth of the Seahawk fleet aircraft broken out between the HSL and HS communities. Figure 3.9 breaks out the growth of the Seahawk fleet by aircraft version.



**FIGURE 3.8 - SEAHAWK FLEET GROWTH BY COMMUNITY**



**FIGURE 3.9 - SEAHAWK FLEET GROWTH BY VERSION**

For the simulation models, the worst-case loading for the consolidated AIMD is when the Seahawk fleet reaches its

peak in FY 97 at 127 aircraft. The number of engines installed in aircraft is double that number, or 254. These are the numbers used at the start of both simulations.

### 3. Mean Time Between Failure

The current demonstrated values for mean time between failure (MTBF) of the Seahawk/T700 system, as well as MTBF values used by the CHWL consolidation proposal, are listed in Table 3.1 below. The thesis will use the latter MTBF values.

**TABLE 3.1 - SEAHAWK/T700 MTBF**

---

Seahawk Type	Current MTBF	Model MTBF
SH-60B	1600 Flight Hrs	1200 Flight Hrs
SH-60F/HH-60H	850 Flight Hrs	900 Flight Hrs

---

Note that the demonstrated MTBF value for the T700 in the SH-60B is 400 hrs higher than the 1,200 hrs used by both CHWL and this thesis. For the SH-60F, the demonstrated MTBF is only 850 hours. However, this low figure is largely due to a salt corrosion problem in the hot section. This problem results from the mission profile of the SH-60F, which often places it in a low hover over the sea (more often than the SH-60B). A fix developed for the problem should increase MTBF in the SH-60F to 1,200 hours. Compared to this figure, the MTBF

of 900 hours used by this thesis is conservative. By using conservative MTBF values, the determination of the required number of engines per year is likely to, in turn, result in a larger more conservative value.

#### **4. Flight Hours / Engine Requirements**

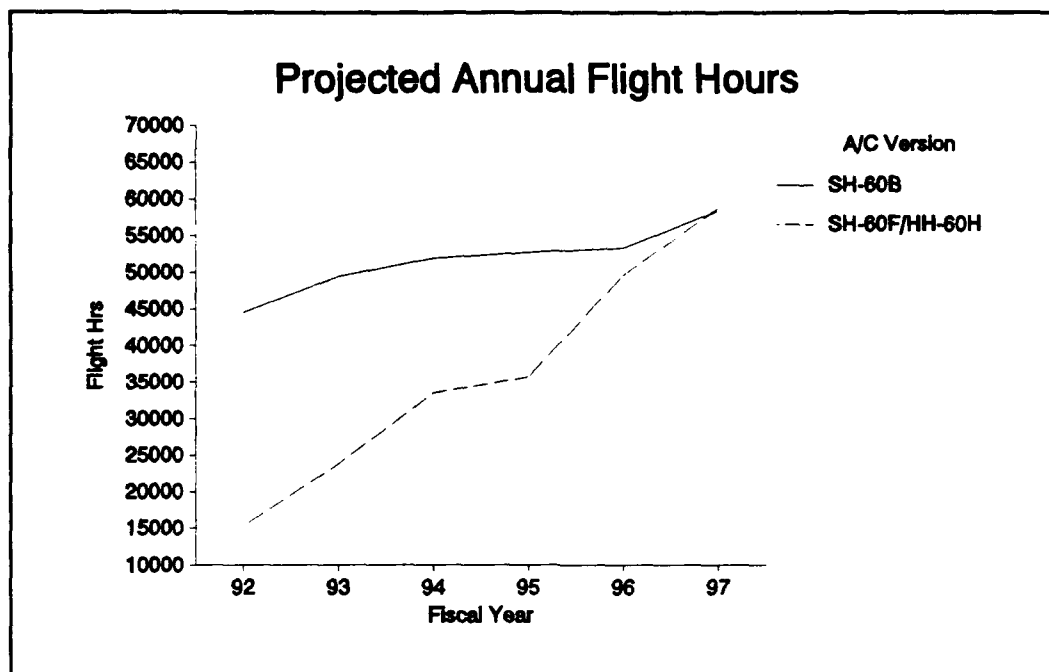
The given values for MTBF and number of aircraft and engines are two important factors needed in the determination of annual engine requirements. A third important factor still needed is the number of flight hours. Projected flight hours per aircraft reported by NAS Mayport in their consolidation proposal are listed in Table 3.2.

**TABLE 3.2 - SEAHAWK FLIGHT HOUR PROJECTIONS  
(HOURS PER AIRCRAFT)**

<b>Fiscal Year</b>	<b>SH-60B</b>	<b>SH-60F/HH-60H</b>
FY92	59.80	44.08
FY93	64.76	55.05
FY94	65.56	63.43
FY95	65.52	67.43
FY96	66.33	79.41
FY97	72.53	81.52

Annual growth in the total number of flight hours is presented graphically in Figure 3.10.





**FIGURE 3.10 - SEAHAWK FLEET FLIGHT HOURS**

Note that growth in the annual flight hours of the Seahawk fleet is due to the combined effects of growth in the number of aircraft and the increased flight hours per aircraft. The growth peaks in FY97, where annual flight hours for the SH-60B and SH-60F/HH-60H reach 58,314 and 58,694 hours, respectively. Worst case engine requirements for the models are derived using these FY97 numbers.

Table 3.3 provides monthly engine requirements in FY97 due to engine failure. The engines per month column in the table represents the average expected number of demands for T700 engines each month.

**TABLE 3.3 - PROJECTED FY97 SEAHAWK ENGINE FAILURES/MONTH**

Seahawk Type	Flt Hrs x # a/c MTBF	No. Engines per month
SH-60B	(72.53 x 67)/1200	4.050
SH-60F/HH-60H	(81.52 x 60)/900	5.435

Besides requirements for engine repairs due to failure, there are additional requirements caused by foreign object damage (FOD). The FOD rate for FY88, FY89, and FY90 was zero. The FOD rate for FY97 for the T700 installed in the SH-60B was 0.107 damaged engines per 1,000 flight hours. Table 3.4 shows the requirements due to FOD in FY97, assuming that the FOD rate remains constant at the FY91 level.

**TABLE 3.4 - PROJECTED FY97 SEAHAWK ENGINE FODS PER MONTH**

Seahawk Type	(Flt Hrs x # a/c x FOD Rate)/1000	FODs per Month
SH-60B	$\frac{72.53 \times 67 \times .107}{1000}$	0.520
SH-60F/HH-60H	$\frac{81.52 \times 60 \times .107}{1000}$	0.523

Summation of engine requirements for failures and FODs from Tables 3.3 and 3.4 results in a monthly total of 10.528 engines. This is an annual requirement for a total of 127 engines. The fact that this number equals the size of the

Seahawk fleet is purely coincidental. However, it does allow another way of readily visualizing the failure rate. With FY97 data, each aircraft has an average of only one engine removal each year, and each engine is removed for failure or FOD an average of only once every two years.

### **5. Engine Spares**

For a single site T700 Intermediate level repair site to be successful, availability of spare engines at the right time and place is essential. Acquisition of sufficient spares is necessary to build RFI engine pools on board ships, forward logistics stock points, and continental U.S. Naval Air Stations. Additional spares are necessary to allow for the inherent delay time involved in the logistics pipeline. Projections made by CHWL for Atlantic Fleet spare engine requirements in support of a single site T700 AIMD are listed in Table 3.5 below. Note that spares for CV packouts as listed in the table only account for four of six Atlantic Fleet carriers. It is not necessary to procure a spares packout for each ship, as all six never deploy at once. Thirty spares in the current Atlantic Fleet inventory.

For the simulation models, the third degree AIMD model uses the maximum projected number of available spares. The first degree repair model is internal to AIMD and does not use supply system spare engines as a resource.

**TABLE 3.5 - PROJECTED T700 SPARE REQUIREMENTS**

Location of Spares Pools/Packups	# of Engines
LAMPS Packups	20
CV Packouts (3 per CV, 4 CVs)	12
NAS Sigonella	4
NAS Mayport	4
NAS Jacksonville	5
NAS Roosevelt Roads	2
Supply System/Logistics Pipeline	10
Total Spares	57

#### **6. Engine and Module Service Times**

The CHWL consolidation proposal used mean service times for various repair activities in its T700 repair synopsis. Both AIMD models also utilize various mean service times to account for the process delays in the simulation. Table 3.6 lists the mean service times used in by the models.

The third degree model uses only the first value in the table, that of the total repair process time for an engine involving module replacement. The first degree model ignores this "generic" service time value and instead uses the mean service time values in the remainder of the table.

**TABLE 3.6 - MEAN SERVICE TIMES**

Work Center	Task	Module	Mean Service Time
41R/450	Full Repair	T700	15.0 hrs
41R	Induct	T700	1.5
411/412	Module Rpr	Hot	25.0
"	"	Cold	25.0
"	"	LPT	15.0
440	"	Accessory	5.0
41R	Buildup Eng	Hot	2.5
"	"	Cold	4.5
"	"	LPT	2.5
"	"	Accessory	2.5
450	Eng Test	Hot	6.5
"	"	Cold	6.5
"	"	LPT	3.0
"	"	Accessory	6.0
41R	QA/Can Eng	T700	3.0

#### **7. Engine Failure Breakout Percentage by Module**

The breakout of T700 engine failures by module changes depending on the time frame involved, engine variant, and source of data. Several breakouts are reproduced in Table 3.7. The AIMD models use an amalgam of these breakdowns, which is also listed in the table. In the third degree repair model (module replacement), the failure mode breakout is

immaterial, since the model assumes infinite availability of replacement modules no matter which one has failed. In the first degree repair model, the breakout is critical since the engine is "married" to the failed module(s), and does not exit the system until repairs are complete. Also, different modules have different mean service times, and as a result have dissimilar effects on work center queue development.

**TABLE 3.7 - ENGINE MODULE FAILURE BREAKOUT**

Module	AEMS Data FY92 - all T700	Mayport Oct91- Apr92 -401	Mayport Oct91- Apr92 -401C	AIMD Model Data -401C
Hot	36.4%	80%	80%	80%
Cold	0.9%	35%	51%	50%
LPT	35.5%	50%	< 1%	9%
Acc Sect	46.7%	0%	< 1%	1%
% Total	119.5%	165%	≈ 133%	140%

Note that all of the percentage totals in Table 3.7 add up to more than 100%. This is due to some engines arriving with more than one failed module. For simplicity, the first degree AIMD model assumes the only dual failure mode is a combination hot section/cold section failure. The assumed failure breakout is 40% dual, 40% hot section, 10% cold section, 9% low power turbine, and 1% accessory, which maintains the Table 3.7 module failure percentages.

#### **D. SIMULATION RESULTS AND ANALYSIS**

For each of the consolidated AIMD models, simulation experiments were run with mean service times using both triangular and log normal distributions. Both distributions produced very similar simulation results, although the average values for all results produced by the triangular distribution were somewhat higher. Ten replications of each simulation were run for 360 time units, with a unit value of one month each. This is equivalent to simulating a 30 year period for each replication. Additionally, the system was allowed to "warm up" and reach a steady operating state before data collection began. The "warm up" period was 36 units, or three years.

The results reported by SIMAN are average values of the variables being tracked in each simulation replication. Appendix C reproduces sample outputs from the simulations. Tables 3.8 and 3.9 summarize the key results of those simulations. Appendix D contains the spreadsheet calculations for the values in Tables 3.8 and 3.9, which were derived using the raw data from the simulation outputs and are the means of the raw data for each characteristic measured.

##### **1. Third Degree AIMD Model**

Table 3.8 shows the means of all results produced by ten simulation replications using the third degree repair

model. In addition to the mean values, the table displays the standard error of the mean in parentheses.<sup>2</sup>

The most important result from simulations using this model is that no aircraft waits in a spare queue for an engine as a result of a maintenance backlog at the AIMD. For the triangular distribution, aircraft turn around time (time in the system) averages 12.79 hours and the aircraft waits for an engine an average of 6.4 hours.<sup>3</sup> However, the aircraft engine removal and installation times at the squadron level built into the model had a mean of 6 hours each. Therefore, the aircraft time in system and aircraft waiting times are functions of squadron maintenance. Note that the "A/C Wait Time" counter starts at the failure generation, counts the

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<sup>2</sup> Standard error (of the mean) is useful in illustrating the consistency of the simulation results. Small standard errors of the mean, as seen in Table 3.8, are indicative that variation of results from one simulation replication to another are, in turn, small. Accordingly, the simulations produce very consistent results from one replication to the next. Standard error of the mean is defined by the expression:

$$SE = \frac{s}{\sqrt{n}}$$

where:

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

$s$  is the sample standard deviation,  $\bar{x}$  is the sample mean, and  $n$  is the number of observations.

<sup>3</sup> It is important to recall that all discussion of times in the simulation models relate to maintenance times only. Administrative and logistics delay times are not incorporated in the models.



engine removal process, and stops at the seizure of the first available spare engine.

**TABLE 3.8 - THIRD DEGREE AIMD MODEL SIMULATION RESULTS**

(Mean values and standard errors from ten replications)

Characteristic	Scenario 1 Mean Values (Std Error)	Scenario 2 Mean Values (Std Error)
A/C Time in System - hours	12.79 (6E-4)	11.98 (0.014)
A/C Time Waiting for Engine - hours	6.40 (4E-4)	5.99 (0.010)
Engine Time in System - hrs	22.97 (0.002)	21.61 (0.033)
# A/C Awaiting Spare	0 (0)	0 (0)
# Engine Spares Used (out of 57)	0.513 (0.002)	0.481 (0.003)
# Engines in Await Repair Queue	0.018 (0.001)	0.017 (0.001)
Repair Channel Utilization - %	24.76 (0.104)	23.22 (0.150)

Scenario 1: Mean Service Time with Triangular Distribution

Scenario 2: Mean Service Time with Log Normal Distribution

Likewise, the engine turn around time (time in the system), which averages 22.97 hours, starts at the failure generation, continues through the engine removal and repair process, and stops when the engine joins the spare pool. Subtracting 6 hours from this average gives an engine awaiting

repair and repair time total average of roughly 19.0 hours. The average number of engines in the awaiting repair queue is 0.018 units, and the average number of spares used is only slightly over half of one engine.

Finally, utilization of the repair channels is only about 25 percent. The third degree repair model used two repair channels. These channels were essentially a combination of work centers 41R and 450, as they provide all the repair functions needed for third degree repair. This model completely ignores the man-hour capacities of work centers 411/412 and 440. These personnel are superfluous for repair at the third degree only.

These simulations show that a consolidated AIMD functioning as a third degree facility in and of itself would have no negative impact on aircraft availability. The results very closely match the turn-around-time of 15 hours for this type of repair mentioned in the CHWL consolidation proposal. This close correlation validates the model with the real-world AIMD, but only when that facility is operated purely as a third degree repair facility.

## **2. First Degree Repair AIMD Model**

A first degree repair facility like AIMD Mayport is more complex than the third degree repair facility modeled in

the previous section. For a more realistic assessment of a consolidated facility, it is necessary to model the real-world situation more closely as was done in this simulation.

Table 3.9 shows the mean values of the results from ten simulation replications of the first degree model.

**TABLE 3.9 - FIRST DEGREE AIMD MODEL SIMULATION RESULTS**

(Mean values and standard errors from ten replications)

Characteristic	Scenario 1 Mean Values (Std Error)	Scenario 2 Mean Values (Std Error)
Engine Time in System - hours	61.37 (0.391)	56.50 (0.209)
# Engines in W/C 41R Queue	0.001 (4E-5)	0.001 (4E-5)
# Engines in W/C 411/12 Queue	0.295 (0.013)	0.245 (0.007)
# Eng-W/C 440 Queue	0 (0)	0 (0)
# Engines in W/C 450 Queue	0.013 (3E-4)	0.013 (3E-4)
W/C 41R - % Utilization	13.22 (0.083)	12.31 (0.065)
W/C 411/412 - % Utilization	56.16 (0.368)	52.14 (0.286)
W/C 440 - % Utilization	0.153 (0.007)	0.147 (0.005)
W/C 450 - % Utilization	20.05 (0.126)	18.64 (0.111)

**Scenario 1: Mean Service Times with Triangular Distribution**

**Scenario 2: Mean Service Times with Log Normal Distribution**

The most important result of this simulation is that there are no significant numbers of engines backing up in awaiting maintenance queues. The largest queue is in module repair, for which, at any given time, there is an average of less than 0.3 of an engine in the queue. In this model, the engine time in system, averaging 61.37 hours for the triangular distribution, is the total of all awaiting maintenance queue times and work center service times. Equating this to a maintenance turn-around time in (16 hour) days results in an average of 3.8 days per engine. In the real-world AIMD, average maintenance related time in system would be somewhat smaller. This is due to the availability of spare modules, which reduce average time spent in the module repair queue.

The results also show the utilization of the work centers. Work center 411/412, module repair, has the highest utilization, at over 56 percent (under the triangular distribution). The lowest utilization in engine repair is that of work center 440 at less than one percent. However, this is to be expected, given that the accessory section assigned in the model to this work center has only a one percent failure rate. (In the real-world AIMD, the bulk of this work center's work load is in repair of the SH-60 APU and small engine components which are not considered in the engine repair model.)

The important point to be observed from the work center utilization rates is not in determining how busy maintenance personnel are. Rather it is the identification of bottlenecks. A work center utilization of 100% may sound efficient to the casual observer, but it is not. In fact it is inefficient. A work center operating at that level of utilization can only do so if there is always another broken engine waiting for the work center to repair it. In short, excessively high utilizations result from awaiting maintenance queues of engines requiring repair waiting to get in to the work center.

Since none of the model results for any work center utilization rate is above 60%, no significant queue development for engines awaiting maintenance occurs. Therefore, the simulation gives a strong indicates that the real-world consolidated AIMD can handle the worst-case repair workload without slowing engines down in awaiting maintenance queues.

### **3. Combination Simulation**

The disadvantage of the first degree repair AIMD model is that it does not give an instantly identifiable indication of the effect of the consolidated AIMD on SH-60 aircraft readiness, as does the third degree model. This

identification is the number of aircraft waiting in a queue for a spare engine.

However, an interesting result is obtained by plugging in the worst-case engine time in system from the first degree model as the mean repair time for the simple third degree model. The resulting "combined" model shows the effect on aircraft readiness of the longer repair time associated with the deeper level of maintenance in the real-world AIMD. Table 3.10 shows the results of the combined simulation.

**TABLE 3.10 - COMBINED AIMD MODEL SIMULATION RESULTS**

(Mean values and standard errors from ten replications)

Characteristic	Scenario 1 Mean Values	Scenario 1 (Std Error)
A/C Time in System - hours	12.79	(0.007)
A/C Time Waiting for Engine - hours	6.39	(0.004)
Engine Time in System - hours	75.17	(0.103)
# A/C Awaiting Spare	0	(0)
# Engine Spares Used (out of 57)	2.127	(0.008)
# Engines in Await Repair Queue	0.103	(0.003)
Repair Channel Utilization - %	50.56	(0.174)

**Scenario 1: Mean Engine Repair Time from First Degree Model used with Triangular Distribution in Third Degree Model**

To account for the increased utilization of other work center man-hours, the combined simulation uses four channels instead of the two channels of the third degree model. Since the results of the previous simulations using the triangular distribution were higher, the combined simulation used the triangular distribution only. This produced more conservative results.

The most significant result of this simulation is that no aircraft are waiting for spare engines. In fact, the average number of spares used was only slightly over two. Therefore, just three spare engines are required to overcome the effects on aircraft of awaiting maintenance queues within the AIMD system. The main purpose of the remaining spare engines is surmounting the effects of administrative and logistics delay times in the real-world system.

The simulation results are essentially estimates which are based on other estimates. However, with the assumptions and data used, they provide strong evidence that a single consolidated T700 AIMD Power Plants division is a feasible and workable concept. The simulation results show that at no time does an aircraft wait for a replacement engine from AIMD (disregarding administrative and logistics delays). Therefore, aircraft availability will not be adversely affected as a result of awaiting maintenance time for AIMD engine repair. Additionally, the results indicate that the consolidated facility can handle the worst case workload

without developing a backlog of awaiting maintenance work. They also provide evidence that AIMD Mayport as a consolidated T700 intermediate maintenance facility can assume more depot-type repairs, such as gas generator repair and complete compressor rotor replacement, at their current manning levels.

Accordingly, the simulation results suggest the Navy can move forward with consolidation and not adversely affect aircraft availability as a result of any intermediate maintenance backlog.



#### IV. COST ANALYSIS

As a primary driver for the consolidation of T700 is cost savings, it is useful to quantify what those savings are, if any. Cost analysis is the method used to quantify those savings. A complete Life Cycle Cost analysis would include all costs associated with a system life cycle. These costs include:

- Research and development costs.
- Production and construction costs.
- Operation and maintenance costs.
- System retirement and phaseout costs.

Cost savings resulting from T700 consolidation analyzed in this thesis fall primarily in the operation and maintenance category, with some also falling in the production and construction category. Potential cost savings in the latter category result from reduced requirements for: initial spare and repair parts provisioning, support equipment acquisition, initial training, and facility construction. Potential cost savings in the operating and maintenance category result primarily from reduced personnel requirements, but also result from reduced overhead, training and spare parts requirements.

#### **A. PRODUCTION AND CONSTRUCTION COSTS**

With a consolidated T700 site there is no necessity to purchase additional support equipment, provision more than one site's supply department with spares, assign additional personnel, or build additional maintenance facilities. Unfortunately, with the T700 there are not many identifiable cost savings in these areas.

For example, NAS Jacksonville already has all required support equipment, tooling, technical manuals, and the test cell required to support second degree repair. It also has most of the equipment on board to support first degree repair. Jacksonville requires only an additional \$192,000 worth of equipment to complete first degree capability, the bulk is already on station. Jacksonville already has completed initial T700 training for its in-house personnel (cross-trained T-58 personnel). The NAS Jacksonville supply department has stocked consumable repair parts to support second degree repair. For the aircraft carriers, the T-58 test cell modifications have already been bought.

All the costs mentioned above are sunk costs, and thus are not recoverable. However, materials and equipment already bought can be used by redistributing them to the single site. Costs not yet sunk include installation costs for the shipboard T-58 test cell mod and construction of the T700 facility at Jacksonville.

## **B. OPERATIONAL AND MAINTENANCE COSTS**

As previously mentioned, a primary area for reducing costs in the T700 consolidation is in the reduction of personnel. Since one site would assume responsibility for all T700 maintenance, it would not be necessary to add billets for extra maintenance personnel to additional intermediate repair sites.

Personnel to fill these billets also require training from the NAMTRADET. The deletion of those additional billets result in considerable cost savings because both personnel costs and training costs incurred to fill the billets are eliminated.

Another generally expected result of a consolidation is reduced overhead. For the T700, this is not the case. Support of T700 engines for the SH-60F at NAS Jacksonville as originally planned would share overhead, (such as supervisory personnel, administration, building maintenance, and utility costs), with the T-56 and T-58 programs. If NAS Jacksonville does not support the T700 at all, the amount of overhead to support the other two engines is virtually the same and no savings result in this area.

Conversely, if NAS Jacksonville is the single site, there might be a few supervisory billets that could be reduced from NAS Mayport AIMD's current levels. However, support by AIMD Jacksonville of all T700s would require additional supervisory billets over their current manning levels. Meanwhile, NAS

Mayport AIMD facilities would remain open for support of other SH-60B components, and continue to incur overhead costs associated with them.

The only way to significantly reduce overhead is by a complete AIMD or even a base closure, where all functions are transferred from one facility to another. For example, NAS Mayport and Naval Station Mayport are undergoing a consolidation that will remove the dual administrative and overhead layers for these virtually co-located facilities. It is not expected or likely that either AIMD Mayport or AIMD Jacksonville will close in the near future. Nevertheless continued reductions in future year defense budgets may necessitate consideration of additional closures.

### **C. LIFE CYCLE CCST ANALYSIS**

This thesis compares costs for two scenarios. The first scenario is NAS Mayport AIMD and NAS Sigonella with first degree capability, NAS Jacksonville AIMD with first or second degree capability, and six Atlantic Fleet carriers with third degree capability. The second scenario is for first degree repair capability at AIMD Mayport only. The analysis does not consider total system costs. Rather the analysis considers only those cost areas that show a difference between scenarios, and thus identify cost savings.

The analysis does not include the cost of building Jacksonville's T700 facility. This is because there are valid

reasons to proceed with its construction even if consolidation occurs (discussed later). Cost savings in the supply area, while quantifiable, would take considerable effort to identify and break out. An entire separate study could be devoted to this area. Therefore, the cost analysis in this thesis does not consider supply spare purchase costs, inventory carrying costs, transportation, and administrative costs. The analysis only considers cost factors mentioned in the section below.

### **1. Cost Factors Used in Analysis**

The CHWL T700 site consolidation proposal used a value of \$29,120 for a man-year for personnel cost comparisons. This figure was derived by using a man-hour cost of \$14.00 per hour and a man-year of 2080 hours (slightly over 173 man-hours per month). The \$14.00 per hour rate applies to all personnel regardless of paygrade.

Another method for determining personnel costs is using the costs budgeted for military personnel utilized in the Military Personnel, Navy (MPN) appropriations. An advantage of using these costs is that they are separated by paygrade. They also eliminate the necessity of defining how many man-hours constitute a man-year. Budgeted MPN costs are listed in Table 4.1. These are the same cost values Ainsworth and Wirwille (1991) used in their thesis.

**TABLE 4.1 - MILITARY PERSONNEL, NAVY COSTS**

Paygrade	MPN Cost per Individual
E-3	\$22,738
E-4	\$26,838
E-5	\$32,643
E-6	\$39,430
E-7	\$46,599
E-8	\$54,164
E-9	\$64,143

NAMTRADET Mayport reports that T700 training costs per student total \$6,435. This cost breaks down into three sections: O&M,N - \$433, MPN - \$3,212, and Student PSA - \$2,790. The cost analysis assumes personnel rotate every three years, and new personnel must be trained to fill the vacated billets. The analysis also assumes all personnel in paygrades E-3 and E-4, and 1/3 of paygrades E-5 and E-6, require training. (Most AIMD Power Plants senior petty officers trained as T700 technicians when they were junior petty officers. However, some arrive from activities with different aircraft and engines, and therefore need transition training for the T700.)

Finally, the assumed cost to install the A/W37-1 modification to the T-58 test cell aboard carriers was 10% of the hardware cost, or \$12,500. The assumed installation rate

for this mod is one in FY 92, two in FY93 and FY94, and one in FY95 for a total of six ships.

## **2. Results of Cost Analysis**

Three cost analyses were done on a spreadsheet program (Quattro Pro) comparing the two scenarios outlined at the start of this section (IV.C). The time frame for each analysis is thirty years, which is the estimated service life of the aircraft. The first analysis used the CHWL man-year figure (\$29,120). The second analysis used the cost values in Table 4.1. Both the first and second analysis assumed no inflation (constant dollars). The third analysis uses Table 4.1 values as well, but assumes that pay increases at a rate of 3% per year. The analysis also assumes that the overall rate of inflation is 5%. Net present values of the inflation adjusted costs were then calculated. Appendix E contains the

**TABLE 4.2 - 30 YEAR LIFE CYCLE COST ANALYSIS RESULTS**

<b>Cost Sources and Assumptions</b>	<b>Total Net Present Value Savings</b>
CHWL Costs, FY92 Dollars	\$32,366,700
MPN Costs, FY92 Dollars	\$32,506,830
MPN Costs, 5% Annual Inflation 3% Annual Pay Increase	\$22,270,985

complete spreadsheets of the life cycle analyses and Table 4.2 provides a summary of their results.

All cost analyses show a significant savings in operating a single T700 intermediate maintenance facility compared to the cost of the originally planned separate facilities. The result obtained from using man-year costs and budgeted MPN costs was surprisingly close, showing over a million present value dollars saved per year. The result obtained by assuming inflation pay increases, while only two-thirds of the net present values of the first two analyses, still represents a savings of over \$22 million over thirty years, or approximately three-quarters of a million dollars per year.

These cost measures alone provide a compelling argument to proceed with consolidated T700 intermediate support for the T700 engine. Quantifying potential supply arena cost savings and factoring them in to the above projections would make the reason for consolidation even more compelling.



## **V. CONCLUSIONS AND RECOMMENDATIONS**

### **A. SUMMARY**

The focus of this thesis has been on determining the feasibility of consolidating intermediate level maintenance for all Atlantic Fleet T700-GE-401 engines. Using simulation, the treatise examined whether a consolidated facility could handle the maximum expected workload. The thesis also used cost analysis to quantify to some degree the amount of savings expected as a result of consolidation. The results of the simulations demonstrate that the consolidated intermediate maintenance facility is feasible and the results of the cost analysis show that the consolidation will save money. Details of these conclusions and recommendations based on them are discussed in the sections below.

### **B. CONCLUSIONS**

The simulation results indicate that a single consolidated T700 AIMD facility can manage the repair workload for all projected Naval Air Forces, Atlantic Fleet T700 engine failures at the worst-case scenario of forecasted failure rate of FY97. The simulations also provide evidence that the consolidated facility can take on additional repair functions currently done at the depot level. In particular, AIMD

Mayport can take over repair of the gas generator from the depot level, without an increase in manning levels.

Even at peak workload, no significant number of engines is in an awaiting maintenance queue. Maintenance in the consolidated facility absorbs no more than three of the total available spare engines. Therefore, aircraft availability is not adversely affected as a result of a maintenance backlog.

Because the simulation models were built on several assumptions, they are not exact duplicates of the real-world AIMD. However, they do replicate the real-world AIMD closely enough to provide useful results. Even better results could be obtained by further development of the models and by use of more detailed service time data. Nonetheless, the simulation results presented here do provide strong indications that the consolidation concept is feasible.

Finally, the cost analyses provide evidence that the consolidated facility will reduce costs. Using different assumptions in the analyses does not affect the certainty of cost savings resulting from consolidation. The only resulting change is in the extent of those savings. The level of savings that is projected is significant enough to make consolidation fiscally worthwhile.

### **C. RECOMMENDATIONS**

In their T700 consolidation proposal, CHWL made several recommendations connected with the consolidation effort.

These are summarized below. The author's comments on these recommendations follow in subsections.

- Drop T700 repair capability at NAS Sigonella. Eliminate the T700 billets, and transfer T700 peculiar support equipment, including the test cell, to AIMD Mayport. Provide forward support in the Mediterranean theater through use of a pool of spare engines at Sigonella.
- Eliminate the T700 capability of the carriers. Cut the SeaOpDet billet and cancel CV test cell modification. Provide support aboard ship by an AVCAL allowance of spare engines.
- Continue the MILCON project for expansion of the AIMD Jacksonville Power Plants facility. The MILCON will expand the engine maintenance area, provide additional storage, and provide an additional test cell pad.
- Retain NAS Mayport as the first degree repair site. Assign two additional Aviation Storekeepers to ASD Mayport. Reduce NAS Jacksonville to a third degree repair site.
- Implementation of the consolidation is contingent on the solution of current "F" condition engines and the acquisition of sufficient spares.

#### **1. Elimination of NAS Sigonella and CV Capability**

Disestablishing the first degree T700 capability at NAS Sigonella, and eliminating the requirement for third degree support aboard ship, results in cost savings relating to personnel reductions. Doing so also eliminates the requirements to forecast the number of engine failures by module type, as well as bit part requirements, and stock the support points accordingly. It is far easier to forecast overall failure rates for engines alone, and stock a pool of

RFI engines. Storage is also simplified and overall storage requirements are reduced. Only engine containers need be stored, not engine containers plus module containers, plus bit parts.<sup>4</sup>

Shutting down NAS Sigonella's T700 capability also provides a needed asset - a second test cell - to AIMD Mayport. Utilization of this valuable asset will also be much higher at Mayport than it is now. With two cells, the consolidated facility will rarely suffer from complete failure of test capability due to a down cell as is presently the case.

## **2. Military Construction Requirement**

The T700 military construction (MILCON) project at NAS Jacksonville should proceed even if that facility does not retain repair capability for the engine. The construction allows for future contingencies if, for example, Naval Station Mayport was added to a base closure list. More importantly, Jacksonville AIMD Power Plants facility needs the additional space even today. A full third of the existing facility is used as a supply storage area for RFI T-58 and T-56 engines, T-56 props, and other components. Shipping and tri-wall

---

<sup>4</sup> It should be noted that a T700 cold section module is shipped in the same container and takes up the same amount of storage space as an entire engine.

containers, and some support equipment are stored outside in the elements.

It may be possible to save money on the construction project by eliminating the shop air and overhead crane requirements. If the new construction was designated as a storage area, the third of the existing facility currently being used for this purpose would be released for other uses. This area already has shop air and crane access features, features which are not now being utilized. Adding them to the new construction is therefore redundant.

### **3. NAS Mayport AIMD as the Consolidated Site**

Choosing AIMD Mayport over AIMD Jacksonville as the consolidated repair site makes sense for several reasons:

- AIMD Mayport can support consolidation at their current manning levels.
- AIMD Mayport is improving and adding to their first degree repair capabilities. The recent addition of compressor rotor replacement capability and the proposed addition of gas generator repair capability are two examples.
- AIMD Mayport Power Plants is dedicated to the T700 repair. AIMD Jacksonville's "plate" is full with stable T-58 and increasing T-56 workloads.
- AIMD Mayport is the current location for the SH-60 NAMTRADET and FRAMP. NAESU and GE representatives are sited there as well.

- Finally, AIMD Mayport has had an established T700 capability for six years. They are further down the T700 repair learning curve than AIMD Jacksonville.<sup>5</sup>

If a pool of RFI spare engines is maintained at NAS Jacksonville, in the author's opinion there is no real need to maintain even a third degree repair capability there. Keeping a third degree repair capability at this site could lead to a requirement, real or perceived, that additional T700 maintenance billets are required. Authorization of these billets would reduce the cost benefit achieved by consolidation.

Additionally, the only support provided by a third degree capability at Jacksonville with consolidated support at AIMD Mayport is support of on-station aircraft. For NAS Jacksonville at the FY97 peak, this will be at most about 40 aircraft at any one time (assuming two deployed squadrons). With the reduced flying hours allocated to deployable

---

<sup>5</sup> The learning curve concept is that the labor-hours to repair an individual unit are lowered as the repair technician learns and gains additional experience through repair of additional units. A learning curve shows a logarithmic shape, in that the initial reductions in labor-hours are high, but after time level off to a nearly constant rate. The learning rate is the slope of this curve.

T.P. Wright developed a model for this concept in 1936. This model can be expressed using the following equation:

$$T_n = T_1 (n^b)$$

where  $T_n$  is the labor-hours to produce the  $n$ th unit,  $b$  is a constant, and  $T_1$  is the labor hours to produce the first unit [see, e.g. Gaither et.al. (1990)].

squadrons while home-based, AIMD Jacksonville would be hard-pressed to see even 40 failed engines annually.

Accordingly, AIMD Jacksonville Power Plants would always stay well behind AIMD Mayport on the learning curve. Maintaining third degree capability there would also require continued stockage of modules and bit parts at two sites. This reduces the effectiveness and savings impact of consolidation on the supply system.

There may be reasons to maintain third degree capability at AIMD Jacksonville that the author is not aware of. One reason may be that the third degree capability being considered for retainment is some sort of limited or degraded capability. For example, a limited third degree capacity with no module replacement and retaining only engine test and minor adjustment capability. If that, or something like it, is the case then perhaps maintenance of this capability at NAS Jacksonville is prudent. If not, however, then consideration should be given to elimination of all T700 capability at NAS Jacksonville and proceeding with full consolidation at NAS Mayport.

#### **4. Current Engine Problems and Spares Requirements**

Proceeding with consolidation outlined in this thesis is predicated on having two major issues: resolving current

T700 maintainability problems, and acquisition of a sufficient number of spare engines.

*a. Current Engine Problems*

The main caveat requiring rectification before implementation of consolidation is the elimination of the large number of engines currently in "F" condition (awaiting repair due to lack of parts). If engines go in to AIMD Mayport and do not come out, even though lack of parts and not lack of maintenance is the cause, the consolidated facility will be perceived as a "black hole." Under such conditions it will be difficult to convince a CV Air Wing Commander or the HS Wing Commander at NAS Jacksonville of the necessity and benefit of giving up his on-site repair capability.

The backlog of "F" condition engines is the result of several subcomponents with a higher number of failures than expected and/or a backlog of required Power Plants Change (PPC) incorporations. Consequently, there are not enough spares of these components to avoid having engines and modules in the repair process hang up in awaiting supply queues. The following components are the principle readiness degraders for the T700:

- Electrical Control Unit (ECU)
- Hydromechanical Control Unit (HMU)
- Anti Ice/Start Bleed Valve (AI/SBV)
- Engine History Recorder(EHR)



- Alternator Stator
- Gas Generator

All the listed components are repaired at the depot level. The first five require only a one-time PPC incorporation at the depot (or contractor). After PPC incorporation, the negative impact of these components on engine readiness will diminish. The gas generator however, will continue as a degrader even after incorporation of its PPC (designed to reduce the impact of hot salt corrosion).

Approval of AIMD Mayport's proposal to add repair capability for this component would therefore enhance engine readiness. By repairing gas generators in-house instead of passing them off-station, logistics pipeline times to the Corpus Christi Army Depot are eliminated. Turn-around times for repair of the gas generator, the hot section, and the engine as a whole would improve as a result. AIMD Mayport's gas generator repair proposal also addresses obtaining this capability on a cost effectiveness basis.

#### ***b. Engine Spares Requirements***

Also crucial to implementation of consolidation is that enough spare engines be available to account for all administrative and logistics delay times, and provide an adequate spare pool or AVCAL allowance at each support site. Without sufficient spares, forward deployed aircraft with an engine requirement would depend on the supply system. It

would doubtless remain in a "down" status until receipt of a replacement engine, a process that could takes days, or even weeks, versus hours for an engine from a pool.

Implementation of the consolidation of T700 intermediate level maintenance can begin upon resolution of the above issues. Appendix F is the consolidation implementation timetable proposed by CHWL.

## **VI. FINAL REMARKS**

Downsizing and fiscal constraints are a current reality faced by all U.S. military services. In the foreseeable future, the Navy and the rest of the military will have to get smarter about accomplishing their missions while reducing costs. The discussion in this thesis of consolidation of maintenance facilities for a single engine is only a very small part of this process. Nevertheless, it is the aggregate implementation of concepts like this that will help reduce the adverse impact of the new budget reality.

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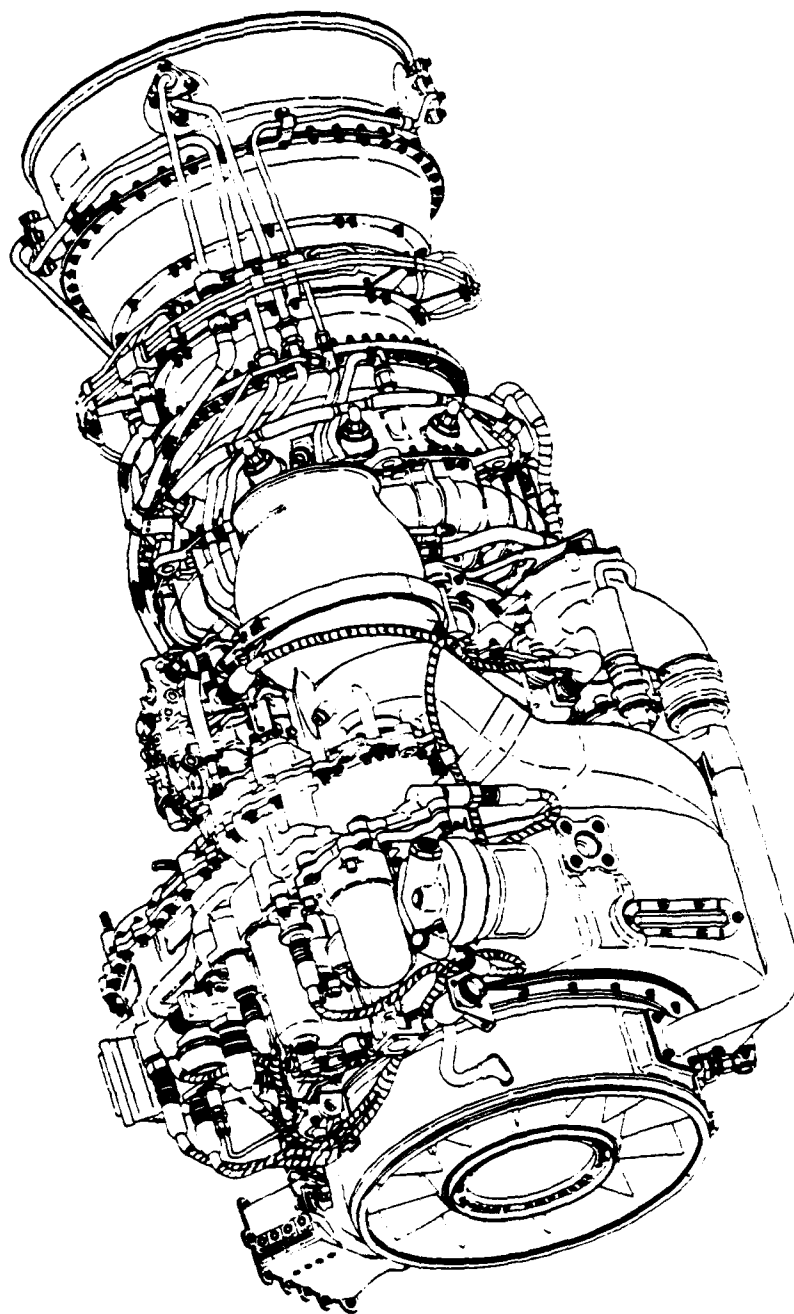
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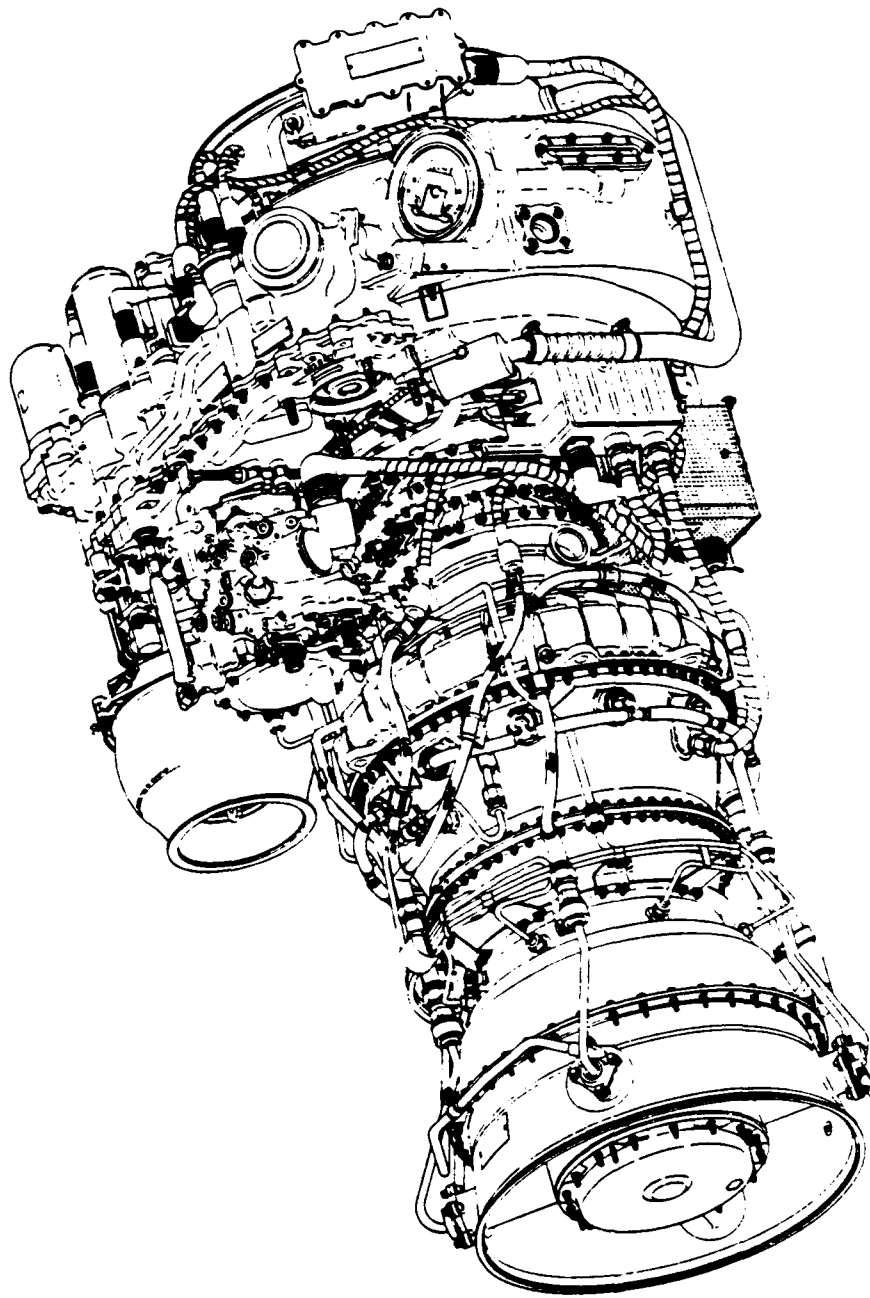
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APPENDIX A



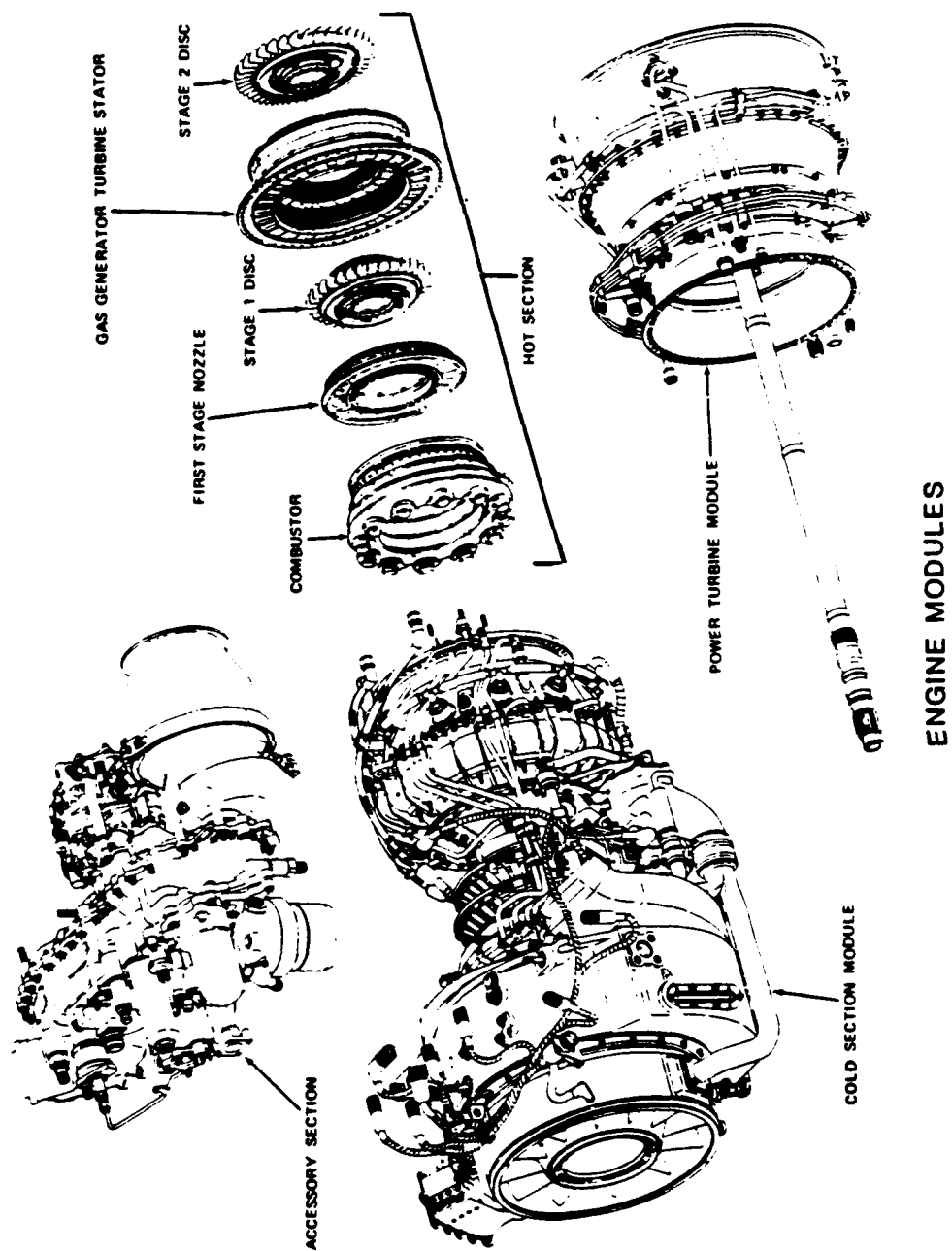
T700-GE-401 ENGINE (LEFT SIDE)

T700-GE-401 Engine (Left Side)



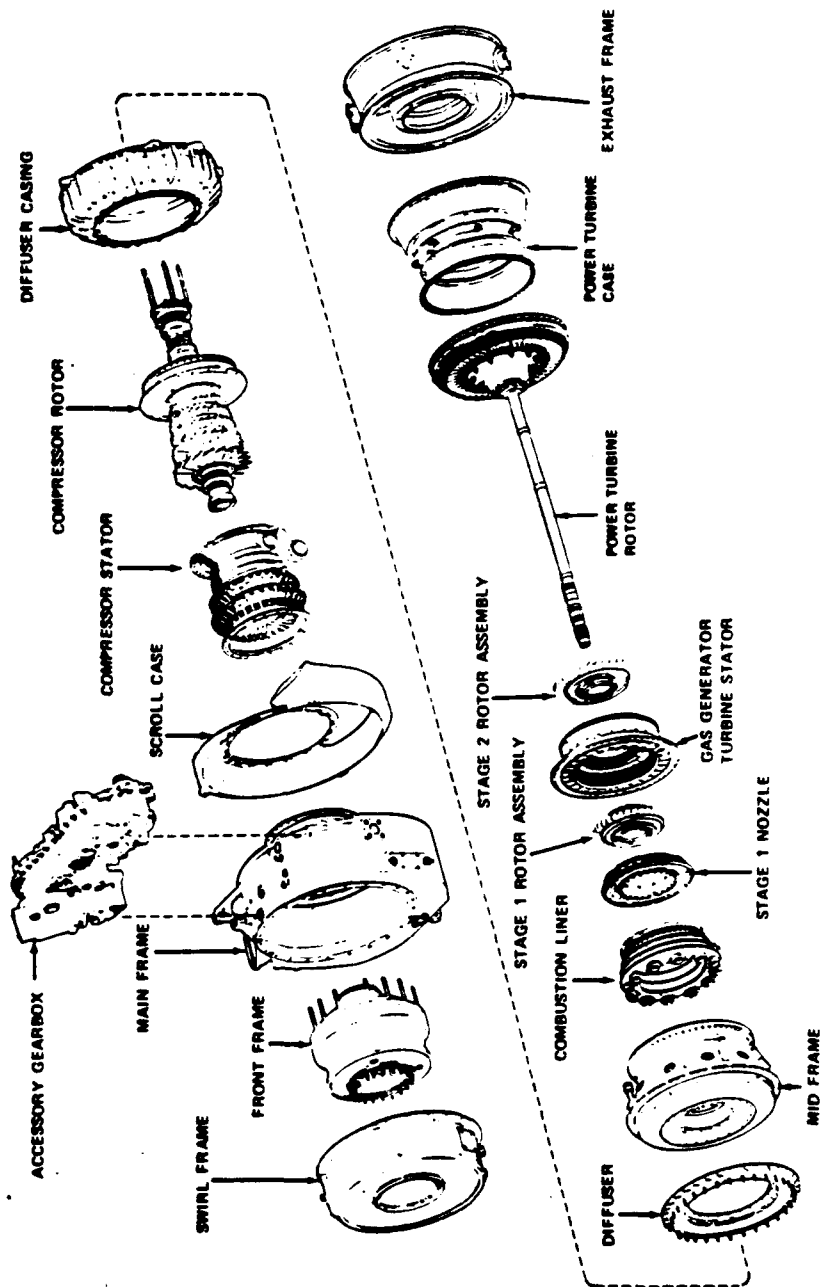
T700-GE-401 ENGINE (RIGHT SIDE)

T700-GE-401 Engine (Right Side)



**T700-GE-401 Engine - View showing Modules**





# MAJOR ENGINE COMPONENTS

T700-GE-401 Engine - Exploded View showing Components

## APPENDIX B

```

BEGIN,Y, T700 3rd Degree AIMD Model;
;
;      SIMULATION MODEL OF SH-60B/SH-60F/HH-60 Engine Repair
;      written by
;      LCDR Jeffrey S. Cook
;      U.S. Naval Postgraduate School
;      Monterey, California
;
;      CREATE,127:0.0,1;
Q1      DELAY: EXPO (12,1);      next engine failure
;      ASSIGN:TimeIn=TNOW;
;
;      DELAY:TRIA(.014118,.017647,.024706); Engine removal
;
;      BRANCH,2:
;          ALWAYS,Aircraft:
;          ALWAYS,Engine;
;
;      SPARE ENGINE POOL QUEUE
;
;      Aircraft  QUEUE,EngSpareQ;      Check the spare engine pool
;      SEIZE:EngSpare;      Install spare engine in aircraft if
;                          available -
;                          Otherwise wait in the EngSpareQ
;      TALLY:AC waiting time, INT(TimeIn);
;      DELAY:TRIA(.014118,.017647,.024706); Engine Installation
;      TALLY:AC time in system,INT(TimeIn):NEXT(Q1);
;                          Collect Turnaround time (TAT)
;                          Fully mission capable (FMC)
;
;      ENGINE MAIN REPAIR CHANNEL QUEUE
;
;      Engine    QUEUE,MainChnlQ;      Queue awaiting engine repair
;      SEIZE:MainChnl;Begin repair cycle
;      DELAY:TRIA(.035294,.044118,.061765); Mean engine repair time 15
hours
;      TALLY:Engine time in system,INT(TimeIn);
;      RELEASE:MainChnl:EngSpare: DISPOSE;
;                          Release the engine repair channel
;                          Update the spare engine pool
END;

```

Third Degree Repair AIMD Model

```

BEGIN;
PROJECT,3rd Deg AIMD TRI Model, Jeffrey S. Cook;
ATTRIBUTES:TimeIn;
QUEUES:EngSpareQ:MainChnlQ;
RESOURCES:EngSpare,57:      ! # of spare engines
              MainChnl,2;      # of repair channels
TALLIES:AC time in system:
              AC waiting time:
              Engine time in system;
DSTAT:NQ(EngSpareQ),ACs await for spare:
              NR(EngSpare),Spare utilization:
              NQ(MainChnlQ),Engines in repair:
              (NR(MainChnl)/2)*100,Eng rpr chnl utilizatn;
SEEDS:1,7664321;      Seed for random number generation.
REPLICATE,10,0,360,No,Yes,36;      Number and duration of
;      experiment replications
END;

```

```

BEGIN;
PROJECT,3rd Deg AIMD LOGN Model, Jeffrey S. Cook;
ATTRIBUTES:TimeIn;
QUEUES:EngSpareQ:MainChnlQ;
RESOURCES:EngSpare,57:      ! # of spare engines
              MainChnl,2;      # of repair channels
TALLIES:AC time in system:
              AC waiting time:
              Engine time in system;
DSTAT:NQ(EngSpareQ),ACs await for spare:
              NR(EngSpare),Spare utilization:
              NQ(MainChnlQ),Engines in repair:
              (NR(MainChnl)/2)*100,Eng rpr chnl utilizatn;
SEEDS:1,1244567;      Seed for random number generation.
REPLICATE,10,0,360,No,Yes,36;      Number and duration of
;      experiment replications
END;

```

Third Degree AIMD Model Experiments -  
Triangular and Log Normal Distributions

```

BEGIN,Y, 1st Deg AIMD Model;
;
;      SIMULATION MODEL OF SH-60B/SH-60F/HH-60 Engine Repair
;      written by
;      LCDR Jeffrey S. Cook
;      U.S. Naval Postgraduate School
;      Monterey, California
;
;      CREATE,127:0.0,1;
Q1      DELAY:EXPO(12,1);
;      ASSIGN:TimeIn=TNOW;      Create New Arrivals
;      ASSIGN:IS=0;
;      ASSIGN:NS = DISCRETE(.4,1,.8,2,.9,3,.99,4,1.0,5);
;      Set repair type
;
Engine  ROUTE:0,SEQ;      Transfer to repair operations
;      STATION,1-4;      Repair action macros
;      QUEUE,M;      Queue awaiting each work center channel
;      SEIZE:WC(M);      Begin repair cycle
;      DELAY:OpTime;      Delay for repair/operation
;      RELEASE:WC(M);      Release work center channel
;      ROUTE:0,SEQ;      Route to next WC in sequence
;      STATION,ExitSystem;      Exit engine/module repair
;      TALLY:Engine Time in System,INT(TimeIn):NEXT(Q1);
;      Release the engine repair channel
;
END;

```

First Degree Repair AIMD Model

```

BEGIN;
PROJECT,1st Deg AIMD TRIA Model, Jeffrey S. Cook;
ATTRIBUTES:TimeIn:OpTime;
STATIONS: 1,Workcenter41R:
          2,Workcenter411:
          3,Workcenter440:
          4,Workcenter450:
          5,ExitSystem;

QUEUES:4;
RESOURCES: WC(4),2,2,1,1; Number of channels/workcenter
SEQUENCES: 1,1,OpTime=TRIA(.003529,.004412,.006176) &
            2,OpTime=TRIA(.117647,.147059,.205882) &
            1,OpTime=TRIA(.010588,.013235,.018529) &
            4,OpTime=TRIA(.015294,.019118,.026765) &
            1,OpTime=TRIA(.007059,.008824,.012353) & ExitSystem:
            2,1,OpTime=TRIA(.003529,.004412,.006176) &
            2,OpTime=TRIA(.058824,.073529,.102941) &
            1,OpTime=TRIA(.005882,.007353,.010294) &
            4,OpTime=TRIA(.015294,.019118,.026765) &
            1,OpTime=TRIA(.007059,.008824,.012353) & ExitSystem:
            3,1,OpTime=TRIA(.003529,.004412,.006176) &
            2,OpTime=TRIA(.058824,.073529,.102941) &
            1,OpTime=TRIA(.010588,.013235,.018529) &
            4,OpTime=TRIA(.007059,.008824,.012353) &
            1,OpTime=TRIA(.007059,.008824,.012353) & ExitSystem:
            4,1,OpTime=TRIA(.003529,.004412,.006176) &
            2,OpTime=TRIA(.035294,.044118,.061765) &
            1,OpTime=TRIA(.005882,.007353,.010294) &
            4,OpTime=TRIA(.014118,.017647,.024706) &
            1,OpTime=TRIA(.007059,.008824,.012353) & ExitSystem:
            5,1,OpTime=TRIA(.003529,.004412,.006176) &
            3,OpTime=TRIA(.011765,.014706,.020588) &
            1,OpTime=TRIA(.005882,.007353,.010294) &
            4,OpTime=TRIA(.007059,.008824,.012353) &
            1,OpTime=TRIA(.007059,.008824,.012353) & ExitSystem;

TALLIES:Engine Time in System;
DSTAT:NQ(1),WC 41R queue:
       NQ(2),WC 411 queue:
       NQ(3),WC 440 queue:
       NQ(4),WC 450 queue:
       (NR(1)/2)*100,WC 41R utilization:
       (NR(2)/2)*100,WC 411 utilization:
       (NR(3)/1)*100,WC 440 utilization:
       (NR(4)/1)*100,WC 450 utilization;

SEEDS:1,2376567;
; Seed for random number generation.
REPLICATE,10,0,360,No,Yes,36;
; Number and duration of experiment replications
END;

```

First Degree AIMD Model Experiment with Triangular Distribution

```

BEGIN;
PROJECT,1st Deg AIMD LOGN Model, Jeffrey S. Cook;
ATTRIBUTES:TimeIn:OpTime;
STATIONS: 1,Workcenter41R:
          2,Workcenter411:
          3,Workcenter440:
          4,Workcenter450:
          5,ExitSystem;

QUEUES:4;
RESOURCES: WC(4),2,2,1,1; Number of channels/workcenter
SEQUENCES: 1,1,OpTime=LOGN(.004412,.001324) &
          2,OpTime=LOGN(.147059,.044118) &
          1,OpTime=LOGN(.013235,.003971) &
          4,OpTime=LOGN(.019118,.005735) &
          1,OpTime=LOGN(.008824,.002647) & ExitSystem:
          2,1,OpTime=LOGN(.004412,.001324) &
          2,OpTime=LOGN(.073529,.022059) &
          1,OpTime=LOGN(.007353,.002206) &
          4,OpTime=LOGN(.019118,.005735) &
          1,OpTime=LOGN(.008824,.002647) & ExitSystem:
          3,1,OpTime=LOGN(.004412,.001324) &
          2,OpTime=LOGN(.073529,.022059) &
          1,OpTime=LOGN(.013235,.003971) &
          4,OpTime=LOGN(.008824,.002647) &
          1,OpTime=LOGN(.008824,.002647) & ExitSystem:
          4,1,OpTime=LOGN(.004412,.001324) &
          2,OpTime=LOGN(.044118,.013235) &
          1,OpTime=LOGN(.007353,.002206) &
          4,OpTime=LOGN(.017647,.005294) &
          1,OpTime=LOGN(.008824,.002647) & ExitSystem:
          5,1,OpTime=LOGN(.004412,.001324) &
          3,OpTime=LOGN(.014706,.004412) &
          1,OpTime=LOGN(.007353,.002206) &
          4,OpTime=LOGN(.008824,.002647) &
          1,OpTime=LOGN(.008824,.002647) & ExitSystem;

TALLIES:Engine Time in System;
DSTAT:NQ(1),WC 41R queue:
      NQ(2),WC 411 queue:
      NQ(3),WC 440 queue:
      NQ(4),WC 450 queue:
      (NR(1)/2)*100,WC 41R utilization:
      (NR(2)/2)*100,WC 411 utilization:
      (NR(3)/1)*100,WC 440 utilization:
      (NR(4)/1)*100,WC 450 utilization;
SEEDS:1,2314532;
; Seed for random number generation.
REPLICATE,10,0,360,No,Yes,36;
; Number and duration of experiment replications
END;

```

First Degree AIMD Model Experiment with Log Normal Distribution

# APPENDIX C

SIMAN IV - License #9050352  
Naval Post Graduate School

Summary for Replication 1 of 1

Project: 3rd Deg AIMD TRI Model      Run execution date : 5/31/1992  
Analyst: Jeffrey S.Cook      Model revision date: 5/31/1992  
Replication ended at time : 360.0

## TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
AC time in system	.03761	.83558E-01	.29266E-01	.48950E-01	3876
AC waiting time	.01881	.11729	.14191E-01	.24628E-01	3876
Engine time in system	.06790	.13907	.51239E-01	.14441	3876

## DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
ACs await for spare	.00000	--	.00000	.00000	.00000
Spare utilization	.52852	1.3938	.00000	5.0000	.00000
Engines in repair	.02204	7.7570	.00000	3.0000	.00000
Eng rpr chnl utilizatn	.50647	1.3209	.00000	2.0000	.00000

Run Time: 1 min(s) 52 sec(s)  
Simulation run complete.

Sample Output from Third Degree AIMD Model

SIMAN IV - License #9050352  
Naval Post Graduate School

Summary for Replication 1 of 1

Project: 1st Deg AIMD TRIA Model      Run execution date : 5/31/1992  
Analyst: Jeffrey S.Cook      Model revision date: 5/31/1992  
Replication ended at time : 360.0

TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
Engine Time in System	.40214	.61216	.42282E-01	1.6599	3654

DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
WC 41R queue	.80723E-03	36.098	.00000	2.0000	.00000
WC 411 queue	1.9585	1.3174	.00000	15.000	1.0000
WC 440 queue	.00000	--	.00000	.00000	.00000
WC 450 queue	.01010	9.9554	.00000	2.0000	.00000
WC 41R utilization	12.760	1.8782	.00000	100.00	50.000
WC 411 utilization	83.343	.37524	.00000	100.00	100.00
WC 440 utilization	.15090	25.723	.00000	100.00	.00000
WC 450 utilization	19.224	2.0498	.00000	100.00	.00000

Run Time: 10 min(s) 53 sec(s)  
Simulation run complete.

Sample Output from First Degree AIMD Model



# APPENDIX D

## SUMMARY OF RESULTS FOR THIRD DEGREE AIMD MODEL WITH TRIANGULAR DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10
A/C TIME IN SYSTEM (MONTHS)	0.03761	0.03771	0.03768	0.03767	0.03754	0.03768	0.03772	0.03757	0.03754	0.03766
A/C WAITING TIME (MONTHS)	0.01881	0.01886	0.01879	0.01879	0.01831	0.01886	0.01886	0.01875	0.01879	0.01883
ENGINE TIME IN SYSTEM (MON)	0.06763	0.06763	0.06777	0.06776	0.06722	0.06741	0.06756	0.06766	0.06744	0.06748
A/C WAITING FOR SPARE (#)	0	0	0	0	0	0	0	0	0	0
SPARE ENGINE UTILIZATION (#)	0.52066	0.51667	0.51763	0.52664	0.50614	0.49918	0.50611	0.51101	0.50978	0.5189
ENGINES IN REPAIR (#)	0.01878	0.0176	0.0191	0.0214	0.01447	0.01634	0.01658	0.01881	0.01882	0.01676
ENGINE REPAIR CHANNEL (%)	25.088	24.903	24.921	25.262	24.634	24.142	24.477	24.61	24.648	25.107
UTILIZATION										

	AVERAGE	STD DEVIATION	STD ERROR
A/C TIME IN SYSTEM (HOURS)	12.79318	0.020239	0.006416
A/C WAITING TIME (HOURS)	6.39676	0.0116	0.003668
ENGINE TIME IN SYSTEM (HRS.)	22.96734	0.064137	0.017138
A/C WAITING FOR SPARE (#)	0	0	0
SPARE ENGINE UTILIZATION (#)	0.513161	0.007779	0.00246
ENGINES IN REPAIR (#)	0.017666	0.001829	0.000678
ENGINE REPAIR CHANNEL (%)	24.7642	0.32954	0.104241
UTILIZATION			

NOTE: ONE AIMD MONTH = 340 HOURS

Summary of Results from Third Degree AIMD Model with Triangular Distribution

# SUMMARY OF RESULTS FOR THIRD DEGREE AIMD MODEL WITH LOG NORMAL DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10
A/C TIME IN SYSTEM (MONTHS)	0.03621	0.03643	0.0362	0.0361	0.03629	0.03634	0.03647	0.03609	0.03609	0.03618
A/C WAITING TIME (MONTHS)	0.01762	0.01776	0.01762	0.01762	0.01767	0.01766	0.01772	0.01741	0.01767	0.01766
ENGINE TIME IN SYSTEM (MON.)	0.06369	0.06362	0.06323	0.06269	0.0631	0.06325	0.06371	0.06315	0.06289	0.06332
A/C WAITING FOR SPARE (#)	0	0	0	0	0	0	0	0	0	0
SPARE ENGINE UTILIZATION (#)	0.49306	0.4922	0.47669	0.46822	0.46237	0.48437	0.48107	0.49362	0.46966	0.46693
ENGINES IN REPAIR (#)	0.02006	0.01871	0.01478	0.0144	0.01461	0.01741	0.0181	0.01627	0.01881	0.0146
ENGINE REPAIR CHANNEL (%) UTILIZATION	23.664	23.675	23.19	22.691	22.393	23.348	23.148	23.668	22.653	23.666

	AVERAGE	STD DEVIATN	STD ERROR
A/C TIME IN SYSTEM (HOURS)	11.9816	0.044616	0.014109
A/C WAITING TIME (HOURS)	6.88672	0.03232	0.01022
ENGINE TIME IN SYSTEM (HRS.)	21.6067	0.104611	0.033049
A/C WAITING FOR SPARE (#)	0	0	0
SPARE ENGINE UTILIZATION (#)	0.480958	0.010661	0.003336
ENGINES IN REPAIR (#)	0.016666	0.001897	0.0006
ENGINE REPAIR CHANNEL (%) UTILIZATION	23.2196	0.4745	0.15006

NOTE: ONE AIMD MONTH = 340 HOURS

Summary of Results from Third Degree AIMD Model with Log Normal Distribution

# SUMMARY OF RESULTS FOR FIRST DEGREE AIMD MODEL WITH TRIANGULAR DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10
ENGINE TIME IN SYSTEM (MOS)	0.18651	0.18351	0.17935	0.17896	0.1777	0.17867	0.18775	0.17533	0.17913	0.17898
WVC 41R QUEUE (#)	0.00109	0.00094	0.00102	0.00101	0.00123	0.00077	0.00084	0.001	0.00084	0.00087
WVC 411/412 QUEUE (#)	0.36269	0.31273	0.29372	0.26299	0.27462	0.2702	0.37405	0.25113	0.27847	0.27275
WVC 440 QUEUE (#)	0	0	0	0	0	0	0	0	0	0
WVC 460 QUEUE (#)	0.01444	0.01355	0.01327	0.01252	0.01202	0.01201	0.014717	0.01257	0.0127	0.01358
WVC 41R UTILIZATION (%)	13.703	12.968	13.253	13.087	13.061	12.841	13.67	13.18	13.241	13.184
WVC 411/412 UTILIZATION (%)	68.034	65.475	66.065	65.861	65.236	64.363	68.402	65.669	66.314	66.173
WVC 440 UTILIZATION (%)	0.132	0.131	0.187	0.153	0.136	0.137	0.169	0.193	0.129	0.171
WVC 460 UTILIZATION (%)	20.8	19.71	20.089	19.716	19.849	19.606	20.748	19.971	20.169	19.967

	AVERAGE	STD DEVIATION	STD ERROR
ENGINE TIME IN SYS (MOS)	0.180489	0.00364	0.001151
ENGINE TIME IN SYSTE (MRS)	61.38626	1.237715	0.3914
WVC 41R QUEUE (#)	0.000961	0.000131	4.13E-05
WVC 411/412 QUEUE (#)	0.296316	0.039866	0.012603
WVC 440 QUEUE (#)	0	0	0
WVC 460 QUEUE (#)	0.013188	0.000893	0.000282
WVC 41R UTILIZATION (%)	13.2198	0.262132	0.082693
WVC 411/412 UTILIZATION (%)	66.1682	1.162942	0.367754
WVC 440 UTILIZATION (%)	0.1527	0.022796	0.007206
WVC 460 UTILIZATION (%)	20.0646	0.404832	0.128019

NOTE: ONE AIMD MONTH = 340 HOURS

Summary of Results from First Degree AIMD Model with Triangular Distribution

# SUMMARY OF RESULTS FOR FIRST DEGREE AIMD MODEL WITH LOG NORMAL DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10
ENGINE TIME IN SYSTEM (MOS)	0.16627	0.16564	0.16325	0.16646	0.16797	0.1696	0.16897	0.16862	0.16562	0.16368
WVC 41R QUEUE (#)	0.00091	0.00088	0.0008	0.00099	0.00117	0.00099	0.00074	0.00103	0.00097	0.00092
WVC 411/412 QUEUE (#)	0.22684	0.2417	0.24625	0.2149	0.27348	0.28863	0.23296	0.26511	0.24446	0.21411
WVC 440 QUEUE (#)	0	0	0	0	0	0	0	0	0	0
WVC 460 QUEUE (#)	0.01271	0.01151	0.01387	0.0126	0.01246	0.01422	0.01309	0.01365	0.01368	0.01216
WVC 41R UTILIZATION (%)	11.963	12.14	12.256	12.354	12.368	12.667	12.063	12.664	12.343	12.313
WVC 411/412 UTILIZATION (%)	60.93	61.486	60.839	62.936	62.238	63.681	61.643	63.338	62.172	62.313
WVC 440 UTILIZATION (%)	0.125	0.146	0.137	0.151	0.186	0.14	0.157	0.162	0.129	0.136
WVC 460 UTILIZATION (%)	18.17	18.298	18.713	18.631	18.676	19.411	18.193	18.926	18.669	18.668

	AVERAGE	STD DEVIATN	STD ERROR
ENGINE TIME IN SYSTEM (MOS)	0.166197	0.001942	0.000614
ENGINE TIME IN SYSTEM (HRS)	66.60358	0.68036	0.208824
WVC 41R QUEUE (#)	0.00094	0.000116	3.62E-06
WVC 411/412 QUEUE (#)	0.244634	0.023436	0.007411
WVC 440 QUEUE (#)	0	0	0
WVC 460 QUEUE (#)	0.013006	0.000823	0.00026
WVC 41R UTILIZATION (%)	12.3051	0.204092	0.06464
WVC 411/412 UTILIZATION (%)	62.1436	0.906207	0.286251
WVC 440 UTILIZATION (%)	0.1467	0.01693	0.006364
WVC 460 UTILIZATION (%)	18.6336	0.349766	0.110606

NOTE: ONE AIMD MONTH = 340 HOURS

Summary of Results from First Degree AIMD Model with Log Normal Distribution

# SUMMARY OF RESULTS FOR COMBINED AIMD MODELS WITH TRIANGULAR DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10
A/C TIME IN SYSTEM (MONTHS)	0.03762	0.03774	0.03768	0.03765	0.03767	0.03764	0.03774	0.03758	0.03756	0.03764
A/C WAITING TIME (MONTHS)	0.01883	0.01886	0.01876	0.01878	0.01883	0.01886	0.01886	0.01877	0.01878	0.01878
ENGINE TIME IN SYSTEM (MON.)	0.22146	0.22261	0.22158	0.22184	0.22066	0.22116	0.22172	0.22022	0.21889	0.22094
A/C WAITING FOR SPARE (#)	0	0	0	0	0	0	0	0	0	0
SPARE ENGINE UTILIZATION (#)	2.1637	2.1667	2.1105	2.137	2.1176	2.1322	2.1268	2.1212	2.1297	2.0809
ENGINES IN REPAIR (#)	0.1081	0.12136	0.10107	0.11426	0.10207	0.10141	0.10803	0.09446	0.08654	0.09487
ENGINE REPAIR CHANNEL UTILIZATION (# OUT OF FOUR TOTAL)	2.0466	2.0443	2.0054	2.0228	2.0166	2.0308	2.0188	2.0267	2.0411	1.9661

	AVERAGE	STD DEVIATION	STD ERROR
A/C TIME IN SYSTEM (HOURS)	12.79488	0.022129	0.008996
A/C WAITING TIME (HOURS)	6.39472	0.011963	0.00378
ENGINE TIME IN SYSTEM (HRS.)	75.1689	0.327176	0.103462
A/C WAITING FOR SPARE (#)	0	0	0
SPARE ENGINE UTILIZATION (#)	2.12663	0.029621	0.008418
ENGINES IN REPAIR (#)	0.103417	0.00832	0.002947
ENGINE REPAIR CHANNEL UTILIZATION	60.56276	0.660861	0.174198

NOTE: ONE AIMD MONTH = 360 HOURS

Summary of Results from Combined AIMD Model with Triangular Distribution

# APPENDIX E

## LIFE CYCLE COST ANALYSIS OF T700 SUPPORT

Scenario 1 - Separate AMDs

Scenario 2 - Consolidated AIMD (Mayport)

\* COSTS ARE SELECTED ADDITIONAL OF  
DIFFERENTIAL COSTS BETWEEN AIMD OPTION  
NOT TOTALS OF ALL POSSIBLE T700 COSTS

YEAR		YEARLY TOTAL	30 YEAR TOTAL
COST of CV TEST CELL			
MOD INSTALLATION	Cost per Ship \$12,500.00	\$12,500	\$75,000
TRAINING COSTS			
	Cost per Man		
CV AIMD	\$8,435.00	\$2,145	\$64,350
NAS MAYPORT AIMD	\$8,435.00	\$38,610	\$1,158,300
NAS JACKSONVILLE AIMD	\$8,435.00	\$25,740	\$772,200
NAS SIGONELLA AIMD	\$8,435.00	\$18,305	\$579,150
PERSONNEL COSTS			
	Cost per Man		
CV AIMD			
6 E-5	\$29,120.00	\$116,480	\$3,494,400
Total		\$116,480	\$3,494,400
NAS MAYPORT AIMD			
2 E-6	\$29,120.00	\$58,240	\$1,747,200
12 E-5	\$29,120.00	\$349,440	\$10,483,200
8 E-4	\$29,120.00	\$232,960	\$6,988,800
4 E-3	\$29,120.00	\$116,480	\$3,494,400
Scenario 1 Total		\$757,120	\$22,713,600
Scenario 2			
2 E-5 (AKZ)	\$29,120.00	\$58,240	\$1,747,200
Scenario 2 Total		\$815,360	\$24,460,800
NAS JACKSONVILLE AIMD			
2 E-6	\$29,120.00	\$58,240	\$1,747,200
8 E-5	\$29,120.00	\$174,720	\$5,241,600
7 E-4	\$29,120.00	\$203,840	\$6,115,200
4 E-3	\$29,120.00	\$116,480	\$3,494,400
Total		\$553,280	\$16,598,400
NAS SIGONELLA AIMD			
1 E-6	\$29,120.00	\$29,120	\$873,600
5 E-5	\$29,120.00	\$145,600	\$4,368,000
5 E-4	\$29,120.00	\$145,600	\$4,368,000
3 E-3	\$29,120.00	\$87,360	\$2,620,800
Total		\$407,680	\$12,230,400
SCENARIO 1			
YR TOTAL		\$1,832,880	
30 YR TOTAL			\$57,865,600
SCENARIO 2			
YR TOTAL		\$853,970	
30 YR TOTAL			\$25,619,100
SCENARIO 2 SAVINGS OVER SCENARIO 1			
		\$1,078,890	\$32,386,700

NOTE: Constant Costs - No assumed pay increases or inflation rate

Life Cycle Cost Analysis with Man-Year Cost and Constant FY92 Dollars

LIFE CYCLE COST ANALYSIS OF T700 SUPPORT  
Scenario 1 - Separate AIMDs  
Scenario 2 - Consolidated AIMD (Mayport)

\* COSTS ARE SELECTED ADDITIONAL OF  
DIFFERENTIAL COSTS BETWEEN AIMD OPTION  
NOT TOTALS OF ALL POSSIBLE T700 COSTS

YEAR		YEARLY TOTAL	30 YEAR TOTAL
COST OF CV TEST CELL			
MOD INSTALLATION			
	Cost per Ship		
	\$12,500 00	\$12,500	\$75,000
TRAINING COSTS			
	Cost per Man		
CV AIMD	\$8,435 00	\$2,145	\$64,350
NAS MAYPORT AIMD	\$8,435 00	\$38,610	\$1,158,300
NAS JACKSONVILLE AIMD	\$8,435 00	\$25,740	\$772,200
NAS SIGONELLA AIMD	\$8,435 00	\$18,305	\$579,150
PERSONNEL COSTS			
	Cost per Man		
CV AIMD			
6 E-5	\$32,643 00	\$130,572	\$3,917,160
Total		\$130,572	\$3,917,160
NAS MAYPORT AIMD			
2 E-6	\$39,430 00	\$78,860	\$2,365,800
12 E-5	\$32,643 00	\$391,716	\$11,751,480
6 E-4	\$28,836 00	\$214,704	\$6,441,120
4 E-3	\$22,736 00	\$90,952	\$2,728,560
Scenario 1 Total		\$776,232	\$23,286,960
NAS JACKSONVILLE AIMD			
2 E-5 (AKZ)	\$32,643 00	\$65,286	\$1,955,560
Scenario 2 Total		\$841,518	\$25,245,540
NAS JACKSONVILLE AIMD			
2 E-6	\$39,430 00	\$78,860	\$2,365,800
6 E-5	\$32,643 00	\$195,856	\$5,875,740
7 E-4	\$28,836 00	\$187,066	\$5,635,960
4 E-3	\$22,736 00	\$90,952	\$2,728,560
Total		\$553,536	\$16,606,060
NAS SIGONELLA AIMD			
1 E-6	\$39,430 00	\$39,430	\$1,182,900
5 E-5	\$32,643 00	\$163,215	\$4,896,450
5 E-4	\$28,836 00	\$134,180	\$4,025,700
3 E-3	\$22,736 00	\$66,214	\$2,046,420
Total		\$405,049	\$12,151,470
SCENARIO 1			
YR TOTAL		\$1,963,669	
30 YR TOTAL			\$58,910,670
SCENARIO 2			
YR TOTAL		\$850,126	
30 YR TOTAL			\$25,403,840
SCENARIO 2 SAVINGS OVER SCENARIO 1			
		\$1,053,541	\$32,506,830
NOTE: Constant Costs - No assumed pay increases or inflation rate			

Life Cycle Cost Analysis with MPN Costs and Constant FY92 Dollars

LIFE CYCLE COST ANALYSIS OF T700 SUPPORT  
Scenario 1 - Separate AIMDs  
Scenario 2 - Consolidated AIMD (Mayport)

\* COSTS ARE SELECTED ADDITIONAL OF  
DIFFERENTIAL COSTS BETWEEN AIMD OPTION  
NOT TOTALS OF ALL POSSIBLE T700 COSTS  
Discount Rate = 0.05

YEAR		1 FY92	2 FY93	3 FY94	4 FY95
COST of CV TEST CELL					
MOD INSTALLATION	Cost per Ship				
	\$12,500.00	\$12,500	\$26,250	\$27,563	\$14,470
TRAINING COSTS					
	Cost per Man				
CV AIMD	\$8,435.00	\$8,435			\$7,449
NAS MAYPORT AIMD	\$8,435.00	\$38,610	\$40,541	\$42,562	\$44,636
NAS JACKSONVILLE AIMD	\$8,435.00	\$25,740	\$27,027	\$28,378	\$29,797
NAS SIGONELLA AIMD	\$8,435.00	\$19,305	\$20,270	\$21,254	\$22,245
PERSONNEL COSTS					
	Cost per Man				
CV AIMD					
6 E-5	\$32,643.00	\$130,572	\$134,489	\$138,524	\$142,660
Total		\$130,572	\$134,489	\$138,524	\$142,660
NAS MAYPORT AIMD					
2 E-6	\$39,430.00	\$78,860	\$81,226	\$83,683	\$86,172
12 E-5	\$32,643.00	\$391,716	\$403,467	\$415,572	\$428,039
8 E-4	\$28,838.00	\$214,704	\$221,145	\$227,779	\$234,613
4 E-3	\$22,738.00	\$90,952	\$93,681	\$96,481	\$99,356
Scenario 1 Total		\$776,232	\$799,519	\$823,505	\$848,210
Scenario 2 Total					
2 E-5 (AK2)	\$32,643.00	\$65,286	\$67,245	\$69,263	\$71,340
Scenario 2 Total		\$841,518	\$866,764	\$892,768	\$919,549
NAS JACKSONVILLE AIMD					
2 E-6	\$39,430.00	\$78,860	\$81,226	\$83,683	\$86,172
6 E-5	\$32,643.00	\$195,858	\$201,734	\$207,786	\$214,019
7 E-4	\$28,838.00	\$187,866	\$193,502	\$199,307	\$205,296
4 E-3	\$22,738.00	\$90,952	\$93,681	\$96,481	\$99,356
Total		\$553,536	\$570,142	\$587,246	\$604,864
NAS SIGONELLA AIMD					
1 E-6	\$39,430.00	\$39,430	\$39,430	\$39,430	\$39,430
5 E-5	\$32,643.00	\$163,215	\$163,215	\$163,215	\$163,215
5 E-4	\$28,838.00	\$134,190	\$134,190	\$134,190	\$134,190
3 E-3	\$22,738.00	\$68,214	\$68,214	\$68,214	\$68,214
Total		\$405,049	\$405,049	\$405,049	\$405,049
SCENARIO 1					
YR TOTAL		\$1,987,979	\$2,023,267	\$2,074,116	\$2,119,563
NET PRESENT VALUE		\$1,987,979	\$1,928,940	\$1,881,284	\$1,830,958
SCENARIO 2					
YR TOTAL		\$880,126	\$907,304	\$935,334	\$964,245
NET PRESENT VALUE		\$880,126	\$864,099	\$848,375	\$832,951

NOTE: Training and Installation Costs rise at same rate as discount/inflation rate (5%)  
Personnel Costs rise at 3% per year

Life Cycle Cost Analysis with MPN Costs, 5% Inflation, and 3% MPN Increase



LIFE CYCLE COST ANALYSIS  
Scenario 1 - Separate AIMDS,  
Scenario 2 - Consolidated

YEAR	5 FY96	6 FY97	7 FY98	8 FY99	9 FY2000
COST of CV TEST CELL MOD INSTALLATION					
TRAINING COSTS					
CV AIMD			\$8,624		
NAS MAYPORT AIMD	\$46,931	\$49,277	\$51,741	\$54,326	\$57,045
NAS JACKSONVILLE AIMD	\$31,287	\$32,851	\$34,494	\$36,219	\$38,030
NAS SIGONELLA AIMD	\$23,465	\$24,639	\$25,871	\$27,164	\$28,522
PERSONNEL COSTS					\$0
CV AIMD					
6 E-5	\$146,980	\$151,369	\$155,910	\$160,567	\$165,405
Total	\$146,980	\$151,369	\$155,910	\$160,567	\$165,405
NAS MAYPORT AIMD					
2 E-6	\$96,756	\$91,420	\$84,163	\$86,986	\$89,597
12 E-5	\$440,880	\$454,106	\$467,729	\$481,781	\$496,214
8 E-4	\$241,651	\$248,901	\$256,388	\$264,059	\$271,961
4 E-3	\$102,387	\$105,438	\$108,601	\$111,859	\$115,215
Scenario 1 Total	\$873,656	\$899,866	\$926,862	\$954,667	\$982,987
2 E-5 (AK2)	\$73,480	\$75,664	\$77,955	\$80,294	\$82,702
Scenario 2 Total	\$947,136	\$975,530	\$1,004,817	\$1,034,961	\$1,065,689
NAS JACKSONVILLE AIMD					
2 E-6	\$96,756	\$91,420	\$84,163	\$86,986	\$89,597
6 E-5	\$220,440	\$227,053	\$233,865	\$240,881	\$248,107
7 E-4	\$211,445	\$217,788	\$224,322	\$231,051	\$237,953
4 E-3	\$102,387	\$105,438	\$108,601	\$111,859	\$115,215
Total	\$623,010	\$641,700	\$660,951	\$680,779	\$701,203
NAS SIGONELLA AIMD					
1 E-6	\$39,430	\$39,430	\$39,430	\$39,430	\$39,430
5 E-5	\$163,215	\$163,215	\$163,215	\$163,215	\$163,215
5 E-4	\$134,190	\$134,190	\$134,190	\$134,190	\$134,190
3 E-3	\$66,214	\$66,214	\$66,214	\$66,214	\$66,214
Total	\$405,049	\$405,049	\$405,049	\$405,049	\$405,049
SCENARIO 1					
YR TOTAL	\$2,150,356	\$2,204,751	\$2,269,501	\$2,318,794	\$2,378,561
NET PRESENT VALUE	\$1,769,105	\$1,727,480	\$1,693,536	\$1,647,924	\$1,609,903
SCENARIO 2					
YR TOTAL	\$994,087	\$1,024,827	\$1,056,556	\$1,089,269	\$1,123,054
NET PRESENT VALUE	\$617,621	\$602,979	\$586,420	\$574,137	\$560,127

LIFE CYCLE COST ANALYSIS  
Scenario 1 - Separate AIMD  
Scenario 2 - Consolidated

YEAR	10 FY2001	11 FY02	12 FY03	13 FY04	14 FY05
COST of CV TEST CELL MOD INSTALLATION					
TRAINING COSTS					
CV AIMD	\$9,983			\$11,556	
NAS MAYPORT AIMD	\$59,297	\$62,892	\$66,036	\$69,338	\$72,808
NAS JACKSONVILLE AIMD	\$39,901	\$41,926	\$44,024	\$46,225	\$48,537
NAS SIGONELLA AIMD	\$29,946	\$31,446	\$33,016	\$34,666	\$36,402
PERSONNEL COSTS					
CV AIMD					
8 E-5	\$170,367	\$175,478	\$180,742	\$186,164	\$191,748
Total	\$170,367	\$175,478	\$180,742	\$186,164	\$191,748
NAS MAYPORT AIMD					
2 E-6	\$102,894	\$105,981	\$109,181	\$112,436	\$115,809
12 E-5	\$511,101	\$526,434	\$542,227	\$558,493	\$575,248
8 E-4	\$260,140	\$268,544	\$277,201	\$286,117	\$295,300
4 E-3	\$118,672	\$122,232	\$125,899	\$129,676	\$133,566
Scenario 1 Total	\$1,012,807	\$1,043,191	\$1,074,467	\$1,106,721	\$1,139,903
2 E-5 (AK2)	\$85,183	\$87,739	\$90,371	\$93,082	\$95,875
Scenario 2 Total	\$1,097,990	\$1,130,930	\$1,164,838	\$1,199,803	\$1,235,778
NAS JACKSONVILLE AIMD					
2 E-6	\$102,894	\$105,981	\$109,181	\$112,436	\$115,809
6 E-5	\$255,550	\$263,217	\$271,113	\$279,247	\$287,624
7 E-4	\$245,123	\$252,478	\$260,050	\$267,852	\$275,896
4 E-3	\$118,672	\$122,232	\$125,899	\$129,676	\$133,566
Total	\$722,239	\$743,906	\$766,223	\$789,210	\$812,556
NAS SIGONELLA AIMD					
1 E-6	\$39,430	\$39,430	\$39,430	\$39,430	\$39,430
5 E-5	\$183,215	\$183,215	\$183,215	\$183,215	\$183,215
5 E-4	\$134,190	\$134,190	\$134,190	\$134,190	\$134,190
3 E-3	\$66,214	\$66,214	\$66,214	\$66,214	\$66,214
Total	\$405,049	\$405,049	\$405,049	\$405,049	\$405,049
SCENARIO 1					
YR TOTAL	\$2,450,221	\$2,503,869	\$2,569,580	\$2,648,903	\$2,707,352
NET PRESENT VALUE	\$1,579,434	\$1,537,171	\$1,502,360	\$1,475,025	\$1,435,766
SCENARIO 2					
YR TOTAL	\$1,157,667	\$1,183,821	\$1,230,894	\$1,269,141	\$1,306,602
NET PRESENT VALUE	\$742,364	\$732,903	\$719,678	\$706,705	\$693,990

LIFE CYCLE COST ANALYSIS  
Scenario 1 - Separate AIMD  
Scenario 2 - Consolidated

YEAR	15 FY06	16 FY07	17 FY08	18 FY09	19 FY10
COST of CV TEST CELL MOD INSTALLATION					
TRAINING COSTS					
CV AIMD		\$13,378			\$13,457
NAS MAYPORT AIMD	\$76,445	\$60,267	\$64,261	\$66,495	\$62,520
NAS JACKSONVILLE AIMD	\$50,983	\$53,512	\$56,187	\$58,997	\$57,948
NAS SIGONELLA AIMD	\$36,223	\$40,134	\$42,140	\$44,247	\$43,460
PERSONNEL COSTS					
CV AIMD					
6 E-5	\$197,502	\$203,427	\$209,530	\$215,816	\$222,290
Total	\$197,502	\$203,427	\$209,530	\$215,816	\$222,290
NAS MAYPORT AIMD					
2 E-6	\$119,263	\$122,861	\$126,547	\$130,344	\$134,254
12 E-5	\$592,506	\$610,261	\$628,589	\$647,447	\$666,870
6 E-4	\$324,759	\$334,502	\$344,537	\$354,873	\$365,515
4 E-3	\$137,573	\$141,700	\$145,951	\$150,330	\$154,840
Scenario 1 Total	\$1,174,121	\$1,209,344	\$1,245,624	\$1,282,993	\$1,321,479
2 E-5 (AKZ)	\$96,751	\$101,713	\$104,765	\$107,905	\$111,145
Scenario 2 Total	\$1,272,871	\$1,311,058	\$1,350,389	\$1,390,901	\$1,433,625
NAS JACKSONVILLE AIMD					
2 E-6	\$119,263	\$122,861	\$126,547	\$130,344	\$134,254
6 E-5	\$296,253	\$305,140	\$314,285	\$323,723	\$333,495
7 E-4	\$264,164	\$262,659	\$301,470	\$310,514	\$319,529
4 E-3	\$137,573	\$141,700	\$145,951	\$150,330	\$154,840
Total	\$837,273	\$862,361	\$886,263	\$914,811	\$942,118
NAS SIGONELLA AIMD					
1 E-6	\$39,430	\$39,430	\$39,430	\$39,430	\$39,430
5 E-5	\$163,215	\$163,215	\$163,215	\$163,215	\$163,215
5 E-4	\$134,190	\$134,190	\$134,190	\$134,190	\$134,190
3 E-3	\$66,214	\$66,214	\$66,214	\$66,214	\$66,214
Total	\$405,049	\$405,049	\$405,049	\$405,049	\$405,049
SCENARIO 1					
YR TOTAL	\$2,779,575	\$2,867,502	\$2,931,074	\$3,010,507	\$3,107,993
NET PRESENT VALUE	\$1,403,674	\$1,379,317	\$1,342,759	\$1,313,474	\$1,287,435
SCENARIO 2					
YR TOTAL	\$1,349,317	\$1,391,325	\$1,434,670	\$1,479,396	\$1,525,545
NET PRESENT VALUE	\$661,497	\$669,251	\$657,239	\$645,456	\$633,597

LIFE CYCLE COST ANALYSIS  
Scenario 1 - Separate AIMD  
Scenario 2 - Consolidated

YEAR	20 FY11	21 FY12	22 FY13	23 FY14	24 FY15
COST of CV TEST CELL MOD INSTALLATION					
TRAINING COSTS					
CV AIMD			\$17,828		
NAS MAYPORT AIMD	\$97,586	\$102,444	\$107,586	\$112,944	\$118,592
NAS JACKSONVILLE AIMD	\$65,044	\$68,296	\$71,711	\$75,296	\$79,067
NAS SIGONELLA AIMD	\$48,763	\$51,222	\$53,783	\$56,472	\$59,286
PERSONNEL COSTS					
CV AIMD					
6 E-5	\$228,959	\$235,828	\$242,902	\$250,189	\$257,695
Total	\$228,959	\$235,828	\$242,902	\$250,189	\$257,695
NAS MAYPORT AIMD					
2 E-6	\$138,281	\$142,430	\$146,703	\$151,104	\$155,637
12 E-5	\$688,876	\$707,483	\$726,707	\$750,569	\$773,056
6 E-4	\$376,485	\$387,779	\$399,413	\$411,396	\$423,737
4 E-3	\$159,485	\$164,289	\$169,196	\$174,273	\$179,502
Scenario 1 Total	\$1,361,126	\$1,401,961	\$1,444,020	\$1,487,341	\$1,531,951
2 E-5 (AKZ)	\$114,479	\$117,914	\$121,451	\$125,095	\$128,848
Scenario 2 Total	\$1,475,607	\$1,519,875	\$1,565,471	\$1,612,436	\$1,660,309
NAS JACKSONVILLE AIMD					
2 E-6	\$138,281	\$142,430	\$146,703	\$151,104	\$155,637
6 E-5	\$343,438	\$353,741	\$364,354	\$375,264	\$386,543
7 E-4	\$329,424	\$339,307	\$349,469	\$359,971	\$370,770
4 E-3	\$159,485	\$164,289	\$169,196	\$174,273	\$179,502
Total	\$970,629	\$999,748	\$1,029,740	\$1,060,632	\$1,092,451
NAS SIGONELLA AIMD					
1 E-6	\$39,430	\$39,430	\$39,430	\$39,430	\$39,430
5 E-5	\$163,215	\$163,215	\$163,215	\$163,215	\$163,215
5 E-4	\$134,190	\$134,190	\$134,190	\$134,190	\$134,190
3 E-3	\$66,214	\$66,214	\$66,214	\$66,214	\$66,214
Total	\$405,049	\$405,049	\$405,049	\$405,049	\$405,049
SCENARIO 1					
YR TOTAL	\$3,177,156	\$3,264,547	\$3,372,699	\$3,447,924	\$3,544,105
NET PRESENT VALUE	\$1,257,309	\$1,230,373	\$1,210,605	\$1,178,672	\$1,153,659
SCENARIO 2					
YR TOTAL	\$1,573,172	\$1,622,319	\$1,673,037	\$1,725,390	\$1,779,400
NET PRESENT VALUE	\$622,758	\$611,435	\$600,524	\$589,621	\$579,322

LIFE CYCLE COST ANALYSIS  
Scenario 1 - Separate AIMD  
Scenario 2 - Consolidated

YEAR	25 FY16	26 FY17	27 FY18	28 FY19	29 FY20
COST of CV TEST CELL MOD INSTALLATION					
TRAINING COSTS					
CV AIMD	\$20,754			\$24,025	
NAS MAYPORT AIMD	\$124,521	\$130,747	\$137,285	\$144,149	\$151,356
NAS JACKSONVILLE AIMD	\$83,014	\$87,165	\$91,523	\$96,066	\$100,904
NAS SIGONELLA AIMD	\$62,261	\$65,374	\$68,642	\$72,074	\$75,676
PERSONNEL COSTS					
CV AIMD					
6 E-5	\$265,426	\$273,369	\$281,590	\$290,036	\$298,739
Total	\$265,426	\$273,369	\$281,590	\$290,036	\$298,739
NAS MAYPORT AIMD					
2 E-6	\$160,306	\$165,115	\$170,069	\$175,171	\$180,426
12 E-5	\$796,278	\$820,166	\$844,771	\$870,114	\$896,216
6 E-4	\$436,449	\$449,542	\$463,029	\$476,920	\$491,227
4 E-3	\$184,867	\$190,433	\$196,146	\$202,031	\$208,093
Scenario 1 Total	\$1,577,920	\$1,625,257	\$1,674,015	\$1,724,236	\$1,775,963
2 E-5 (AK2)	\$132,713	\$136,694	\$140,765	\$145,019	\$149,370
Scenario 2 Total	\$1,710,633	\$1,761,952	\$1,814,810	\$1,869,255	\$1,925,332
NAS JACKSONVILLE AIMD					
2 E-6	\$160,306	\$165,115	\$170,069	\$175,171	\$180,426
6 E-5	\$398,139	\$410,083	\$422,366	\$435,057	\$448,109
7 E-4	\$361,663	\$363,350	\$405,150	\$417,305	\$429,524
4 E-3	\$184,867	\$190,433	\$196,146	\$202,031	\$208,092
Total	\$1,125,225	\$1,158,981	\$1,193,751	\$1,229,563	\$1,266,450
NAS SIGONELLA AIMD					
1 E-6	\$39,430	\$39,430	\$39,430	\$39,430	\$39,430
5 E-5	\$163,215	\$163,215	\$163,215	\$163,215	\$163,215
5 E-4	\$134,190	\$134,190	\$134,190	\$134,190	\$134,190
3 E-3	\$66,214	\$66,214	\$66,214	\$66,214	\$66,214
Total	\$405,049	\$405,049	\$405,049	\$405,049	\$405,049
SCENARIO 1					
YR TOTAL	\$3,664,169	\$3,745,962	\$3,851,655	\$3,965,233	\$4,074,140
NET PRESENT VALUE	\$1,136,141	\$1,108,193	\$1,063,269	\$1,067,436	\$1,039,267
SCENARIO 2					
YR TOTAL	\$1,635,154	\$1,692,699	\$1,752,095	\$2,013,403	\$2,076,669
NET PRESENT VALUE	\$569,022	\$556,919	\$549,009	\$539,267	\$526,750

LIFE CYCLE COST ANALYSIS  
 Scenario 1 - Separate AIMD  
 Scenario 2 - Consolidated

YEAR	30-YEAR TOTALS	PRESENT VALUE	PRESENT VALUE SUBTOTALS
COST of CV TEST CELL MOD INSTALLATION			
	\$80,783	\$75,000	\$75,000
TRAINING COSTS			
CV AIMD	\$135,817	\$84,350	
NAS MAYPORT AIMD	\$2,585,204	\$1,158,300	
NAS JACKSONVILLE AIMD	\$1,710,136	\$772,200	
NAS SIGONELLA AIMD	\$1,262,802	\$579,150	
	\$5,693,559		\$2,574,000
PERSONNEL COSTS			
CV AIMD			
6 E-5	\$6,212,017	\$3,005,151	
Total	\$6,212,017		\$3,005,151
NAS MAYPORT AIMD			
2 E-6	\$3,751,797	\$1,814,985	
12 E-5	\$18,636,052	\$9,015,452	
8 E-4	\$10,214,632	\$4,941,472	
4 E-3	\$4,327,079	\$2,093,285	
Scenario 1 Total	\$36,929,560		\$17,865,193
2 E-5 (AK2)	\$3,106,009	\$2,221,236	
Scenario 2 Total	\$40,035,569		\$19,387,769
NAS JACKSONVILLE AIMD			
2 E-6	\$3,751,797	\$1,814,985	
6 E-5	\$9,318,026	\$4,507,726	
7 E-4	\$6,937,803	\$4,323,786	
4 E-3	\$4,327,079	\$2,093,285	
Total	\$26,334,705		\$12,739,784
NAS SIGONELLA AIMD			
1 E-6	\$1,182,900	\$636,443	
5 E-5	\$4,896,450	\$2,634,465	
5 E-4	\$4,025,700	\$2,165,971	
3 E-3	\$2,046,420	\$1,101,047	
Total	\$12,151,470		\$6,537,926
SCENARIO 1			
YR TOTAL	\$87,402,095		
NET PRESENT VALUE	\$42,797,053		\$42,797,053
SCENARIO 2			
YR TOTAL	\$42,600,773		
NET PRESENT VALUE	\$20,526,069		\$20,526,069
SCENARIO 2 SAVINGS OVER SCENARIO 1			\$22,270,985

## **APPENDIX F**

### **T700 AIMD Consolidation Implementation Time Line**

#### **Fourth Quarter FY92**

- Establish NAVSUPO Jacksonville spare RFI engine pool (referred to as the "pool" hereafter) at two engines.
- Establish NAVSUPO Sigonella pool at three engines.
- Disestablish T700 SeaOpDet.
- Cancel AIMD Sigonella T700 billets.

#### **First Quarter FY93**

- Establish NAVSUPO Roosevelt Roads, Puerto Rico, pool at one engine.
- Downgrade NAVSUPO Mayport pool to four engines.
- Solution of gas generator problem.
- Fund and upgrade Mayport to two test cells.
- Provide ASD Mayport with two AK billets.

#### **Second Quarter FY93**

- Close AIMD Sigonella T700 work center.
- Transfer AIMD Sigonella PSE to AIMD Mayport.
- Transfer NAVSUPO Sigonella T700 assets to NAVSUPO Mayport.

#### **Fourth Quarter FY93**

- Increase NAVSUPO Jacksonville pool to three engines.

#### **First Quarter FY94**

- Increase NAVSUPO Sigonella pool to four engines.
- Increase NAVSUPO Roosevelt Roads pool to three engines.
- Reconvene CHWL working group for reevaluation.

#### **Fourth Quarter FY94**

- Increase NAVSUPO Jacksonville pool to four engines.

#### **Second Quarter FY96**

- Increase NAVSUPO Jacksonville pool to five engines.

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1